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STOCKAGE POLICY ANALYSIS. ANNEX A. COMPONENT DOCUMENTATION OF D--ETC(U)
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(1) LEVEL III

(6) STOCKAGE POLICY ANALYSIS.

ANNEX A.

COMPONENT DOCUMENTATION

OF

DoD INSTRUCTION 4140.39

VSL/EOQ POLICY IMPLEMENTATION.

PART 1.

AUGUST 31, 1980

(11) 31 Aug 80

(12) 210

STOCKAGE POLICY ANALYSIS

ANNEX A

COMPONENT DOCUMENTATION

OF

DoD INSTRUCTION 4140.39

VSL/EOQ POLICY IMPLEMENTATION

PART 1

AUGUST 31, 1980

ANNEX A
PART 1 CONTENTS

1.0 INTRODUCTION

Introduction

A. OMB Issue

OMB expressed concern about the ability of individual item managers to arbitrarily adjust buy quantities and about the impact of VSL/EOQ policies on long supply inventory.

B. Tasking

In order to provide the basis for a response to OMB, the Working Group was tasked to document how the Components have implemented the policies of DoD Instruction 4140.39, "Procurement Cycle and Safety Levels of Supply for Secondary Items", in their automated materiel management systems for repairables and nonrepairables. In addition, the Working Group was tasked to document the parameters, constraints and controls used by the individual Components in conjunction with implementation of VSL/EOQ policies.

C. Results

The Component representatives on the Working Group documented their implementation of the VSL/EOQ policies of DoD Instruction 4140.39 through the use of presentations to the Working Group members. Part 1 and Part 2 of this Annex contain the individual Component presentations and the associated narrative as presented to the members of the Working Group. In addition, each Components documented the parameters, constraints and controls used in connection with implementation of VSL/EOQ policies which are contained in Section 3 of Part 2 of this Annex.

D. Conclusions

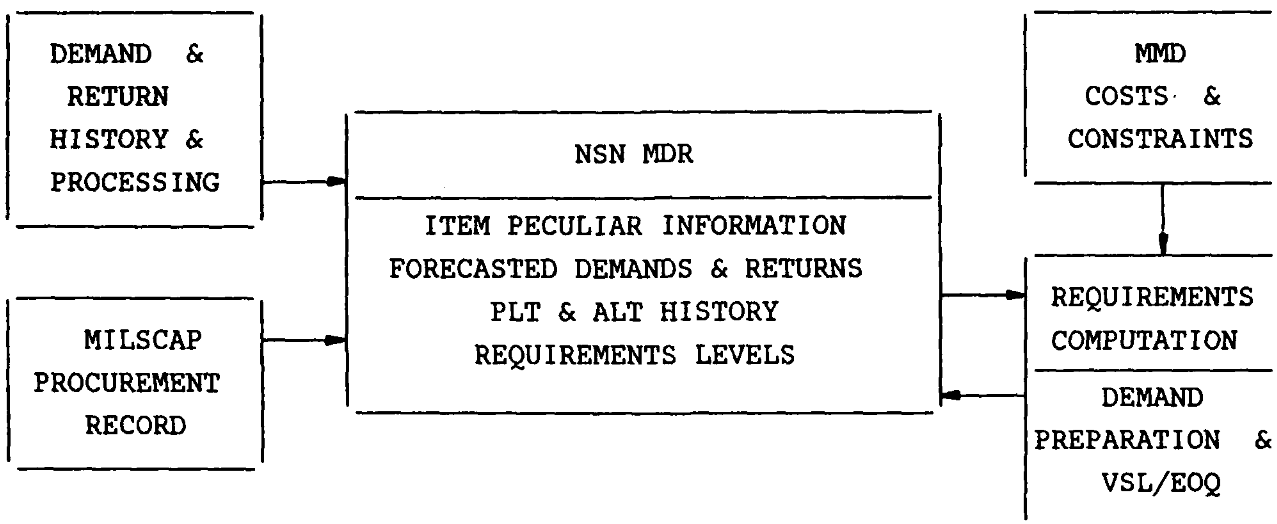
Based upon analysis of the individual Component implementation presentations as well as documented parameters, constraints and controls, the Working Group concluded that each Component complied with the intent of DoD Instruction 4140.39. However, several policy issues were identified during analysis of Component implementation of VSL/EOQ policies which require OASD action. These policy issues are addressed in detail in the body of the final report and are listed here for information purposes only:

1. Computation of Obsolescence Rate
2. Use of Nonrecurring Demand Observations in Forecasting Demand for Inventory Levels
3. Range Rule for Stockage after Demand Development Period
4. Budget Formulation and Budget Execution Performance Goals
5. Replacement Costs Used in Models
6. Forecasting Leadtime Variance and Leadtime Demand Variance
7. Probability Distribution of Leadtime Demand
8. Frequency of Procurement Reviews
9. Demand Forecasting
10. Use of Serviceable Returns in Forecasting and Requirements Offsets
11. Controls over VSL/EOQ Parameters and Constraints
12. Constraints on Safety Level

2.0 ARMY DOCUMENTATION OF VSL/EOQ IMPLEMENTATION

ARMY IMPLEMENTATION OF VSL/EOQ POLICIES

OVERVIEW OF REQUIREMENTS SYSTEM



Slide #1

OVERVIEW OF REQUIREMENTS SYSTEM

On this chart is a simplified schematic of the Army's system for developing requirements. The heart of the system is the National Stock Number Master Data Record (NSNMDR) which is a repository of relevant data peculiar to an NSN. In addition to basic item data like unit price, and study method, the NSNMDR also stores forecasted demands, forecasted lead times, and recent leadtime history, which are fed to it by other processes.

Demand estimates are fed to the NSNMDR in several forms. There is a base Average Monthly Demand (BAMD) which is analogous to an estimate of recurring demand, a schedule of estimated demands from overhaul facilities, a schedule of initial issue and provisioning requirements, a schedule of demands from set assembly operations, and some other infrequently used demand types. Procurement leadtime history is fed to the NSNMDR by the MILSCAP process, and from this a forecasted Administrative Leadtime (ALT) and Production Leadtime (PLT) are produced.

The above information is passed from the NSNMDR to the Requirements Determination and Execution System (RD&ES) where procurement cycles and safety levels are computed. The RD&ES also receives other data from the Material Management Decision File (MMD) such as cost to hold, cost to procure, and shortage cost value. When the levels are computed, they are fed back to the NSNMDR where they are used in procurement decisions.

ARMY IMPLEMENTATION OF VSL/EOQ POLICIES

DATA COLLECTION SYSTEMS

- o DEMANDS AND RETURNS
  - oo TWO YEAR HISTORY OF MILSTRIP TRANSACTIONS IS MAINTAINED BY EACH ICP
    - ooo TAPE FILE SORTED BY NIIN
    - ooo DAILY TRANSACTIONS INCLUDING ADJUSTMENTS TO EXISTING TRANSACTIONS ARE QUEUED FOR MONTHLY UPDATE TO MAIN FILE
    - ooo GEOGRAPHIC AREA CODE IS ADDED TO THE RECORD BASED UPON THE DOCUMENT INITIATOR
- o OVERHAUL DEMANDS ARE CAPTURED AT THE OVERHAUL FACILITY
  - oo ICP's PROVIDED WITH AN OVERHAUL FACTOR WHICH REPRESENTS THE NUMBER OF PARTS EXPECTED TO BE USED IN THE OVERHAUL OF 100 ITEMS

Slide #2

DATA COLLECTION SYSTEMS

The Army maintains two years of MILSTRIP transaction history at each ICP. This is kept on a voluminous tape file called the Demand, Return and Disposal (DRD) file, which is updated monthly. When changes to an existing MILSTRIP document occur, the changes are recorded against that document number. The file does not contain two records with the same document number.

In addition to the basic MILSTRIP information some other codes are added to the document record to facilitate subsequent processing. A program code is added which identifies the type of demand, e.g., initial issue, foreign military sales, overhaul, or mobilization. In this way certain types of demand can be isolated for separate forecasting procedures. Codes which identify geographic/customer areas are also added so that demand estimates may be made by these breakouts. The other basic demand data collection system exists at each overhaul facility. The result of this system is an estimate of the amount of a given part used in the overhaul of 100 items. This is called the Depot Overhaul Factor (DOF).

ARMY IMPLEMENTATION OF VSL/EOQ POLICIES

DATA COLLECTION SYSTEMS (CONTINUED)

- o DEMANDS AND RETURNS (CONTINUED)
  - oo OVERHAUL FACILITY MAINTAINS RECORD OF DEMANDS BY PROGRAM WHILE THE PROGRAM IS ACTIVE
  - oo FACTORS ARE UPDATED WHEN THE OVERHAUL PROGRAM IS CLOSED AND THEN TRANSMITTED TO RESPONSIBLE ICP
  - oo FACTORS DEPEND ON TYPE OF PROGRAM
- o PROCUREMENT LEAD TIME (PROLT)
  - oo PRODUCTION LEAD TIME (PLT)
    - ooo TIME FROM WHEN CONTRACT IS SIGNED UNTIL AT LEAST 1/3 OF CONTRACTED AMOUNT IS DELIVERED
    - ooo RECORD OF EACH CONTRACT WHICH IS OPEN OR CLOSED IN PREVIOUS TWO YEARS IS MAINTAINED

Slide #3

DATA COLLECTION SYSTEMS
(Continued)

While an overhaul program is active, the facility collects the demands for parts made by the maintenance shop for that program. When the program ends, that history is expressed as the number of demands per 100 overhauls and is combined with the previous DOF by way of an exponential smoothing estimate. The weight given to the new factor depends upon the number of items overhauled during the program. The more items overhauled, the larger the weight. A separate DOF is kept for each type of overhaul, e.g., remove and repair as necessary, complete overhaul, battle damage, etc.

Whenever a new DOF is computed, it is transmitted to the ICP which manages the part. It is then used in a procedure called the Parts Explosion Process which estimates demands for future overhaul programs.

Procurement leadtime history is maintained on the NSNMDR by Contract Line Item Number (CLIN). Generally, there is a record for each open CLIN plus any which have been closed in the previous two years. Each CLIN has an associated ALT. When a PLT is recorded, that is also associated with the CLIN. The Army measures a PLT when at least 1/3 of the CLIN amount is delivered.

ARMY IMPLEMENTATION OF VSL/EOQ POLICIES

DATA COLLECTION SYSTEMS (CONTINUED)

- o PROCUREMENT LEADTIME (CONTINUED)
  - oo INFORMATION COMES FROM MILSCAP
  - oo PLT IS RECORDED WHEN 1/3 OF AMOUNT IS RECEIVED; OTHERWISE THERE IS AN ESTIMATED PLT RECORDED FOR THE CONTRACT
- o PROCUREMENT ADMINISTRATIVE LEADTIME (ALT)
  - oo TIME FROM INITIATION OF A PROCUREMENT REQUEST UNTIL A CONTRACT IS SIGNED
  - oo RECORDED ON SAME FILE AS PLT

Slide #4

DATA COLLECTION SYSTEMS
(Continued)

All procurement leadtime information in the NSNMDR is generated by the Military Standard Contract Administration Procedures (MILSCAP) process and fed to the NSNMDR.

ARMY IMPLEMENTATION OF VSL/EOQ POLICIES

DATA COLLECTION SYSTEMS (CONTINUED)

- REPAIR CYCLE TIME (RCT)
  - REPAIR LEADTIME (RLT)
    - IN SHOP TIME
    - MEASURED FROM FIA FILE AS AVERAGE TIME FROM CONDITION CODE M TO CONDITION CODE A
  - REPAIR ADMINISTRATIVE LEADTIME
    - TIME FROM WHEN AN UNSERVICEABLE ITEM ARRIVES AT THE REPAIR FACILITY UNTIL IT IS INDUCTED <u>IF</u> A REQUIREMENT EXISTS
    - NO MEASUREMENT SYSTEM PRESENTLY

Slide #5

DATA COLLECTION SYSTEM
(Continued)

The Repair Cycle Time (RCY) is defined as the sum of the Repair Leadtime (RLT), the Repair Administrative Leadtime (RALT) and the Repair Accumulation Time (RAT). RLT is the in shop time and is measured from the Financial Inventory Accounting file as the time from Condition Code M to Condition Code A. An average is used to forecast RLT.

RALT is defined as the time from when an unserviceable item arrives at the overhaul facility until it is inducted if a requirement exists. Because of problems in defining when a requirement exists, there is no measurement system presently.

ARMY IMPLEMENTATION OF VSL/EOQ POLICIES

FORECASTING

o OVERVIEW OF ARMY DEMAND FORECASTING

- oo FORECASTING PROCEDURES DEPEND ON MANAGEMENT INTENSITY GIVEN AN ITEM
- oo BASE AMD VS OTHER REQUIREMENTS
  - ooo BASE AMD
    - AKIN TO RECURRING DEMAND
    - DEMANDS WHICH ARE EXPECTED TO RECUR, ALBEIT RANDOMLY, EXCLUDING THOSE DEMANDS WHICH ARE THOUGHT TO BE BETTER FORECAST SEPARATELY
    - BASE AMD MAY BE KEPT BY CUSTOMER AREA
    - MODIFIED BY PROGRAM BEFORE USED IN REQUIREMENTS DETERMINATION

Slide #6

FORECASTING

A brief overview of the Army's demand forecasting procedures is given on this slide.

Generally, the procedures used on an item depend upon the management intensity given the item. The more the management intensity, the more the detail used in forecasting demands. For example, on items with low annual dollar value of demand (< $5,000) which are of general use, virtually all demand types are used to form an average demand rate. This is then the only forecast of demand made for that item. A higher dollar value item (> $5,000), on the other hand, may have overhaul demands forecasted separately through the Parts Explosion Process mentioned earlier, with all other demands contributing to the BAMD.

The BAMD is the estimate of future demands made from an historical average of demands. It is like recurring demand in that it represents the demands which are expected to occur in the future according to how they occurred in the past. Excluded from the BAMD are those demand types which receive separate forecasts like overhaul or initial issue. The BAMD may be kept by customer area and is modified by program size before it is used in requirements determination.

ARMY IMPLEMENTATION OF VSL/EOQ POLICIES

FORECASTING (CONTINUED)

o OTHER REQUIREMENTS

- oo OVERHAUL DEMANDS
- oo SET ASSEMBLY
- oo INITIAL ISSUE REQUIREMENTS
- oo PROVISIONING REPLENISHMENT REQUIREMENTS
- oo OTHERS

Slide #7

FORECASTING
(Continued)

Demand requirements which may be forecasted through separate procedures are overhaul demands, set assembly demands, initial issue, and provisioning replenishment. Other types of demands which the item manager wishes to forecast can be entered manually.

ARMY IMPLEMENTATION OF VSL/EOQ POLICIES

FORECASTING (CONTINUED)

o DEMAND FORECASTING

oo BASE AMD

ooo MOVING AVERAGE OF PAST DEMANDS IN BASE PERIOD

- BASE PERIOD IS USUALLY TWO YEARS BUT MAY BE SET BY ITEM MANAGER

ooo FOR LOW DOLLAR VALUE ITEMS VIRTUALLY ALL DEMANDS GO INTO BASE AMD

ooo FOR HIGH DOLLAR VALUE ITEMS RECURRING DEMAND PLUS A FRACTION OF NON-RECURRING DEMAND GO INTO BASE AMD

- FRACTION IS SET BY ICP

ooo COMPUTED MONTHLY

ooo BASE AMD IS MODIFIED BY PROGRAM TO FORM A QUARTERLY SCHEDULE OF DEMANDS

Slide #8

FORECASTING
(Continued)

On this chart demand forecasting is discussed in more detail. The BAMD is computed by a moving average technique. Normally, the base period is two years, but the item manager may choose smaller base periods of 6, 12, or 18 months if he thinks there is a trend.

For Low Dollar Value (LDV) Items, virtually all demands except initial issue, provisioning replenishment, mobilization and grant aid are included in BAMD. For High Dollar Value (HDV) items, in addition to the above demand types, overhaul and set assembly demand are also excluded from BAMD. Moreover, only a fraction of the remaining demands which are coded non-recurring are included in BAMD.

The BAMD is updated monthly. Before it is used in requirements computation it is updated by future program size. The result is a quarterly schedule of base demand.

ARMY IMPLEMENTATION OF VSL/EOQ POLICIES

FORECASTING (CONTINUED)

- OVERHAUL DEMAND
  - OVERHAUL FACTOR APPLIED TO OVERHAUL PROGRAM TO PRODUCE ESTIMATED DEMAND BY QUARTER
  - FORECASTS UPDATED QUARTERLY
  - USED FOR HDV ITEMS AND ITEMS WHICH ARE ONLY DEMANDED BY OVERHAUL ACTIVITY
- PROVISIONING REPLENISHEMENT DEMAND
  - USES MAINTENANCE FACTOR MODIFIED BY DEMAND AND WEIGHTED BY PROGRAM
- INITIAL ISSUE REQUIREMENTS
  - PRODUCED BY SPECIAL SYSTEM AND FED TO REQUIREMENTS SECTOR

Slide #9

FORECASTING
(Continued)

Overhaul demands, as mentioned previously, are computed by the Parts Explosion Process. This process takes each projected overhaul program, applies the DOF for each part and produces a quarterly schedule of forecasted demands by program. Then the forecast is summed for each repair part over all programs on which the part is used. This process is done quarterly. For the most part it is used only on HDV items and LDV items which are used only by overhaul facilities.

Provisioning replenishment demand is forecast as required by DoD Instruction 4140.42, and uses a weighted average of maintenance factor estimate with actual experience.

Initial issue requirements are *computed by a special system using maintenance* factors, deployment schedules, and retail supply structure and policies. These are used as a quarterly schedule to the NSNMDR requirements sector.

ARMY IMPLEMENTATION OF VSL/EOQ POLICIES

FORECASTING (CONTINUED)

- o RETURNS
  - oo UNSERVICEABLE RETURNS
    - ooo UNSERVICEABLE RETURN RATE (URR) = RATIO OF AVERAGE MONTHLY UNSERVICEABLE RETURNS IN BASE PERIOD TO BASE AMD
    - ooo FORECASTED FUTURE UNSERVICEABLE RETURNS = (URR)(FORECASTED BASE DEMANDS)
    - ooo UPDATED MONTHLY
  - oo SERVICEABLE RETURNS
    - ooo NOT EXPLICITLY FORECAST
    - ooo SERVICEABLE RETURNS ARE NETTED FROM DEMANDS BEFORE BASE AMD IS COMPUTED
      - \- INDICATES DEMANDS WHICH SHOULD HAVE BEEN CANCELLED

Slide #10

FORECASTING
(Continued)

Unserviceable returns are treated as though they are linearly related to BAMD. An Unserviceable Return Rate (URR) is computed as the ratio of average monthly unserviceable returns in the base period to the BAMD. Forecasts of future returns are made for each quarter by applying URR to the forecast of base demands for that quarter.

Serviceable returns are not explicitly forecast by the Army although the system has the capability to do this implicitly. A percentage of serviceable returns is netted from demands before BAMD is computed. This percentage may be from 0 to 100 and is set by the ICP. The rationale for this approach is that a serviceable return indicates a demand which should have been cancelled or never made.

ARMY IMPLEMENTATION OF VSL/EOQ POLICIES

FORECASTING (CONTINUED)

- o AVERAGE DEMAND SIZE
  - oo RATIO OF BASE AMD TO BASE AVERAGE MONTHLY DEMAND FREQUENCY
  - oo UPDATED MONTHLY
- o PROCUREMENT LEADTIME
  - oo AVERAGE OF REPRESENTATIVE PLT's AND ALT's MEASURED IN PREVIOUS TWO YEARS
    - ooo ITEM MANAGER DETERMINES IF OBSERVATION IS REPRESENTATIVE AND ENTERS APPROPRIATE CODE IN FILE
  - oo CHANGE UNDER WAY
    - ooo IF PLT NOT YET RECORDED ON A CONTRACT USE TIME FROM SIGNATURE IF THAT TIME EXCEEDS THE AVERAGE OF RECORDED PLT's
    - ooo MODIFY AVERAGE PLT's BY GROUP AVERAGE

Slide #11

FORECASTING
(Continued)

Average demand or requisition size is computed as the ratio of BAMD to base average monthly demand frequency. The same demands which contribute to BAMD are used to compute the monthly demand frequency. This is updated monthly along with BAMD.

Procurement leadtime (PROLT) is forecast as the average of representative ALT plus PLT of those CLINs which are on the NSNMDR. The item manager or a procurement specialist determines if a recorded ALT or PLT is representative and codes the record accordingly. PROLT forecasting is in a state of change right now. Significant changes underway are to use the time from signature to present if there is no recorded PLT for a given CLIN provided that time is larger than the average of all other recorded PLT's for that NIIN. Also, a technique is being implemented to modify the item average PLT by a group average if there is not much item information on PLT.

ARMY IMPLEMENTATION OF VSL/EOQ POLICIES

FORECASTING (CONTINUED)

- o LEADTIME DEMAND VARIABILITY
  - oo EMPIRICAL RELATIONSHIP OF PERCENT FORECAST ERROR TO ANNUAL DOLLAR VALUE AND ANNUAL DEMAND FREQUENCY
  - oo VARIABILITY IS MEASURED WITH RESPECT TO FORECAST: IT IS NOT MEANT TO BE THE VARIABILITY OF THE DEMAND PROCESS
  - oo STANDARD DEVIATION OF LEADTIME DEMAND (σ) =

$$\frac{(\text{PCER})\ (\text{GAMMA})\ (\text{PROLT-DEMAND})}{\sqrt{\text{PROLT} * 1.333}}$$

    - ooo PCER = PERCENT FORECAST ERROR FOR A 9 MONTH DEMAND FORECAST FROM TABLE
    - ooo $\sqrt{\text{PROLT} * 1.333}$ CONVERTS PCER TO PROLT SIZE
    - ooo (PROLT-DEMAND) (PCER) IS ESTIMATE OF MAD
    - ooo GAMMA CONVERTS MAD TO STANDARD DEVIATION

Slide #12

FORECASTING
(Continued)

PROLT demand variance is estimated from an empirical relationship of percent forecast error to annual dollar value and annual demand frequency. Presently, the Army does not include the contribution of leadtime variability to leadtime demand variance. Variability is attributed solely to the demand process.

Percentage forecast error as used by the Army is a measure of the mean absolute deviation of 9 months of demand relative to its corresponding moving average forecast. Consequently, if the forecasted demand for 9 months is known, an estimate of the mean absolute deviation for that forecast is produced by applying the percent error to the forecast.

In order to use this technique for general leadtime demand variance the formula on the chart is used. The factor $\sqrt{\text{PROLT X 1.333}}$, where PROLT is measured in years, converts the PCER from a nine month measure to the PCER for the length of the PROLT. The GAMMA factor converts the resulting mean absolute deviation to standard deviation. GAMMA depends on the leadtime distribution used by the model.

ARMY IMPLEMENTATION OF VSL/EOQ POLICIES

FORECASTING (CONTINUED)

o UNIT PRICE

oo FOR STOCK FUND ITEMS PRICE IS UPDATED ONLY AT THE BEGINNING OF THE FISCAL YEAR

ooo NEW PRICE = LATEST PURCHASE PRICE PLUS AN INFLATION FACTOR & SURCHARGE = STANDARD PRICE

oo FOR APPROPRIATION ITEMS PRICE IS UPDATED WHENEVER A NEW PRICE IS INCURRED

Slide #13

FORECASTING
(Continued)

The unit price used in requirements computation by the Army is the standard price. Consequently, it follows DOD guidelines for update. Stock fund items are updated once per year on 1 October, while appropriation items are updated with each new experience.

ARMY IMPLEMENTATION OF VSL/EOQ POLICIES

PROGRAM DATA

- USED ROUTINELY TO ADJUST BASE AMD
- VIRTUALLY ANY TYPE OF PROGRAM CAN BE USED, BUT ONLY IN-USE DENSITY AND FLYING HOURS ARE USED
- QUARTERLY PROGRAM FOR NEXT 5 YEARS AND PREVIOUS 2 YEARS IS MAINTAINED BY AREA
    - CONSIDERABLE MANUAL EFFORT BY END ITEM MANAGER
    - NO STANDARD PROCEDURES AMONG ICP's FOR MAINTAINING PROGRAM DATA, BUT DATA IS UPDATED AT LEAST YEARLY
- PROGRAM CHANGE FACTOR (PCF) BY AREA IS PROGRAM FOR FUTURE QUARTER/ AVG PROGRAM DURING BASE PERIOD
- FORECASTED BASE DMEANDS BY AREA FOR FUTURE QUARTER = (PCF) (BASE AMD)

Slide #14

PROGRAM DATA

Program Data us used routinely by the Army to adjust BAMD before it is used in computations of requirements levels. Virtually any type of program information may be used in the system, however, in-use density and flying hours, and to a lesser extent, rounds fired and miles travelled, are the only types of program actually used. The system maintains estimates of program size for the next 5 years as well as the actual program size for the previous 2 years. All of this is handled by the end item manager and requires some considerable *manual effort. Each ICP has its own procedures* for maintaining program data. Generally, however, it is updated at least yearly, but no more frequently than twice per year.

A Program Change Factor (PCF) is computed for a given future quarter as the ratio of average program size in the base period to the forecasted program size for the quarter. There is a separate PCF for each geographic area. Forecasted base demands from a geographic area nad computed as the (PCF)(BAMD) for that area.

ARMY IMPLEMENTATION OF VSL/EOQ POLICIES

PROGRAM DATA (CONTINUED)

- UNSERVICEABLE RETURNS ARE ALSO ADJUSTED BY PROGRAM SINCE:

  UNSERVICEABLE RETURN FORECAST = (URR) (FORECASTED BASE DEMANDS)

- OVERHAUL AND SET ASSEMBLY DEMAND ARE ALSO FORECASTED USING PROGRAM DATA
  - FORECASTED DEMAND BY QUARTER =

    (CONSUMPTION FACTOR) (PROGRAM DURING THE QUARTER)

- PROVISIONING REQUIREMENTS ARE ALSO PROGRAM DEPENDENT BUT USE MAINTENANCE FACTOR IN VARYING DEGREES IN PLACE OF BASE AMD
  - INITIAL ISSUE REQUIREMENTS USE RAW MAINTENANCE FACTOR
  - REPLENISHMENT REQUIREMENTS USES MODIFIED MAINTENANCE FACTOR

Slide #15

PROGRAM DATA
(Continued)

Note that since unserviceable returns are forecasted as a percent of base demands that they too are program dependent. Overhaul and set assembly demand are also forecasted using future program schedules and estimates of usage. Provisioning estimates are made based on projected deployment schedules and estimated maintenance factors.

ARMY IMPLEMENTATION OF VSL/EOQ POLICIES

REQUIREMENTS DETERMINATION

- o WHAT TO STOCK
  - oo COSDIF MODEL FROM DODI 4140.42
    - ooo SHORTAGE COST PARAMETER SET YEARLY; SET ACCOMODATION EQUAL TO OPERATIONAL READINESS TARGET OF WEAPON SYSTEM
    - ooo COSDIF MODEL IS RUN MONTHLY
      - ITEMS NOT STOCKED OR NSO_2 ARE STOCKED IF THEY PASS COSDIF
      - ITEMS STOCKED ARE RETAINED AS STOCKED IF THEY FAIL COSDIF BUT HAVE BEEN STOCKED < ONE YEAR OR HAVE BEEN IN SYSTEM < FOUR YEARS
    - ooo ITEM MANAGER MAY ADD ITEMS AS NSO_2 STOCKAGE IF THEY FAIL COSDIF AND HE BELIEVES THEY SHOULD BE STOCKED
      - NSO_2 ITEMS ARE ESSENTIALLY TREATED LIKE STOCKED ITEMS

Slide #16

REQUIREMENTS DETERMINATION

There are two prime aspects to requirements determination apart from requirements forecasting. They are determining what items to stock, and then determining how much to stock.

The Army uses the Cost Differential (COSDIF) model from DoD Instruction 4140.42 to determine what items to stock. The shortage cost in COSDIF is adjusted yearly so that the accomodation for a weapon system is equal to the Operational Readiness Target for the weapon system. Operational readiness is basically the percent of time the weapon system is able to operate as required.

Monthly, the basic cycle for requirements computation, the COSDIF model is run. Items which were not stocked become stocked if they pass COSDIF. Likewise, Numeric Stockage Objective Type 2(NSO_2) items, which are items stocked for essentiality purposes become regular stocked items if they pass COSDIF. If a stocked item flunks COSDIF and has been stocked for less than one year it remains a stocked item. Otherwise, it becomes a non-stocked item. Items which have been established as stocked items during provisioning remain stocked for at least 4 years regardless of the COSDIF calculations. THe item manager may stock an item as an NSO_2 item if it fails COSDIF but the manager considers it essential to stock. NSO_2 items are treated, for all practical purposes, just like normal stocked items. NSO_2 is an important category for low-density, high operational capability systems.

ARMY IMPLEMENTATION OF VSL/EOQ POLICIES

REQUIREMENTS DETERMINATION (CONTINUED)

- o VSL/EOQ MODEL
  - oo DODI 4140.39 MODEL FOR CONSUMABLES AND REPAIRABLES
    - ooo IMPLEMENTED THROUGHOUT ICP's FROM JUNE 1974 TO JANUARY 1977
  - oo GENERAL
    - ooo SEVERAL ELEMENTS OF THE MODEL WERE SELECTED BY SIMULATION ANALYSIS USING 6 YEARS OF ACTUAL DEMAND HISTORY (SEE "EVALUATION OF SEVERAL VSL/EOQ MODELS", IRO REPORT, MAY 1974)
      - APPLY HOLDING COST TO ON-HAND OR TO TOTAL ASSETS
      - PROCUREMENT CYCLE COMPUTATION
      - LEADTIME DEMAND PROBABILITY DISTRIBUTION
      - DEMAND VARIANCE ESTIMATOR
    - ooo ONE ALTERNATIVE BETTER THAN ANOTHER IF IT ACHIEVED BETTER DAYS WAIT FOR THE SAME SUPPLY COST WITHIN A REASONABLE OPERATING REGION

Slide #17

REQUIREMENTS DETERMINATION
(Continued)

From June 1974 to January 1977 the Army implemented the VSL/EOQ model of DoD Instruction 4140.39. Both consumable and repairable items are covered by this model. Many of the particulars of the model were left open by the DoD Instruction. The Army attempted to select as many as possible of these elements from simulation analysis with real demand history. An alternative was considered better than another if it achieved better days wait for the same supply cost within a reasonable operating region. Specific elements evaluated this way were application of holding cost, procurement cycle formula, leadtime demand distribution, and demand variance estimation.

ARMY IMPLEMENTATION OF VSL/EOQ POLICIES

REQUIREMENTS DETERMINATION (CONTINUED)

- o APPLICATION OF HOLDING COST
  - oo APPLY TO TOTAL ASSETS
- o PROCUREMENT CYCLE
  - oo APPROXIMATION TO THE THEORETICAL OPTIMUM OF THE DODI 4140.39 TOTAL VARIABLE COST (TVC) EXPRESSION WITH THE LAPLACE DISTRIBUTION
  - oo $EOQ = \frac{\sigma}{\sqrt{2P}} + \sqrt{\frac{\sigma^2}{2P^2} + \frac{Q^2w}{P}}$
    - ooo Qw = WILSON $Q = \sqrt{\frac{2Cp \cdot D}{C_H} \cdot (1-URR)}$
    - ooo Cp = PROCUREMENT COST
    - ooo C_H = HOLDING COST
    - ooo D = YEARLY DEMAND AS ESTIMATED FOR VSL/EOQ (BASE DEMANDS + AVERAGE MONTHLY OVERHAUL DEMANDS)
    - ooo σ = STANDARD DEVIATION OF LEADTIME DEMAND
    - ooo $P = (1 + e^{-\sqrt{2}Qw/\sigma})/(1 - e^{-\sqrt{2}Qw/\sigma})$

Slide #18

REQUIREMENTS DETERMINATION
(Continued)

DoD Instruction 4140.39 allows the user of the model to apply holding cost to either expected on-hand inventory, or the expected on-hand plus on-order inventory. On a theoretical basis, neither approach is strictly correct. However, the Army decided to apply holding cost to total on-hand plus on-order since it gave the best results in the simulator which has a much more realistic cost structure than the DoD Instruction 4140.39 analytic model.

Two techniques were tried for computing the procurement cycle. The Wilson EOQ was compared to an approximation to the theoretically optimum Q from the DoD Instruction 4140.39 model using the Laplace distribution for leadtime demand. Again by way of the simulator, the approximation to the theoretical optimum was found best. The formula is shown on the accompanying chart, and is explained in detail in "Evaluation of Several VSL/EOQ Models" by the Army Inventory Research Office, May 1974.

ARMY IMPLEMENTATION OF VSL/EOQ POLICIES

REQUIREMENTS DETERMINATION (CONTINUED)

- IF Q^* IS THEORETICAL OPTIMUM Q THEN $Q_W < EOQ < Q^*$
- PROCUREMENT CYCLE MONTHS (PC) = $\frac{(12)(EOQ)}{D(1-URR)}$
  - CONSTRAINED SO THAT $3 \leq PC \leq 36$
    - ASKING FOR EXTENSION TO 60 MONTH MAXIMUM
  - PC IS THE OUTPUT FROM VSL/EOQ MODEL
- PROCUREMENT CYCLE QUANTITY IS COMPUTED BY APPLYING ALL FORECASTED DEMANDS NETTED BY RETURNS TO THE PROCUREMENT CYCLE MONTHS

Slide #19

REQUIREMENTS DETERMINATION
(Continued)

If Q* is the Theoretical Optimum Q, and Qw is the Wilson Q, then the Army EOQ is such that $Qw < EOQ < Q^*$. That is, the approximation is always closer to Q* than is Qw, but it does not exceed Q*.

The EOQ as computed by the model is not used explicitly. Before the model computations are done, the EOQ is converted to months and is referred to as the procurement cycle. The procurement cycle is constrained to be between 3 and 36 months. The procurement cycle is an output of the model. The EOQ quantity is used no further. In order to get the procurement cycle quantity, all forecasted demands, offset by unserviceable returns, are applied to the procurement cycle months. Since demands are normally time phased, a summing procedure is used over all the months which constitute the procurement cycle period. The procurement cycle period begins a procurement leadtime in the future, and ends a procurement cycle later. The procurement cycle quantity then becomes part of the requirements objective, and is used in actual buy decisions.

ARMY IMPLEMENTATION OF VSL/EOQ POLICIES

REQUIREMENTS DETERMINATION (CONTINUED)

- o SAFETY LEVEL
  - oo VALUE WHICH MINIMIZES TVC GIVEN THAT Q = EOQ FROM ABOVE. THE DELIVERY CYCLE QUANTITY IS USED INSTEAD OF EOQ FOR MULTIPLE DELIVERY ITEMS
  - oo EXPECTED LEADTIME DEMAND (LTD) AND STANDARD DEVIATION (σ)
    - ooo CONSUMABLE ITEM
      - \- LTD = (D)(PROLT)
      - \- σ IS COMPUTED AS DESCRIBED IN FORECASTING SECTION
    - ooo REPARABLE ITEM
      - \- LTD = (D)(RCY) + (D)(1-URR)(PROLT-RCY) IF RLT $\leqq$ PROLT
= (D)(PROLT) IF RCY > PROLT
      - \- $\sigma^2 = (A)(\sigma^2_{CONS}) + (1-A)[URR^2\sigma^2_{CONS} + (URR)(1-URR)(PROLT)(D)]$
        - -- A = RCY/PLT

Slide #20

REQUIREMENTS DETERMINATION
(Continued)

Safety level (SL) is computed as the value which minimizes the DoD Instruction 4140.39 Total Variable Cost (TVC) expression using the EOQ as described previously. If the item is to be delivered in phases, the delivery cycle quantity is used instead of EOQ since the amount delivered is a determinant of supply performance, and since the SL is selected to achieve an implied target stock availability.

If the item is consumable the expected leadtime demand (LTD) is set to (D)(PROLT) where D is an estimated average of random demand. The standard deviation σ is computed as described earlier in the forecasting section.

If the item is repairable then:

$$LTD = (D)(RCY) + (D)(1\text{-}URR)(PROLT\text{-}RCY)$$
$$\text{if } RCY < PROLT$$
and
$$LTD = (D)(PROLT)$$
$$\text{otherwise were } RCY \geq PROLT$$

The standard deviation is modified for repairable items as shown on the chart. This modification assumes that each demand for a repairable item has a probability of URR of being accompanied by an unserviceable return. It is felt that this assumption is more reasonable than the other obvious alternative assumption that demands and returns are independent.

ARMY IMPLEMENTATION OF VSL/EOQ POLICIES

REQUIREMENTS DETERMINATION (CONTINUED)

- oo REPARABLE ITEMS CONTINUED

  $\sigma^2 = \sigma^2 CONS$ IF RLT ≧ PROLT

o LEADTIME DEMAND DISTRIBUTION

- oo IF LTD ≧ 20 USE NEGATIVE BINOMIAL; OTHERWISE USE LAPLACE

o SL = R-LTD

- oo R IS OPTIMUM REORDER POINT FROM TVC
- oo O ≦ SL ≦ MIN(LTD, 3σ)
  - ooo ARE REQUESTING CHANGE TO O ≦ SL ≦ 3σ
- oo SL IS THE OUTPUT FROM VSL/EOQ MODEL AND BECOMES A PART OF THE REORDER WARNING POINT

Slide #21

REQUIREMENTS DETERMINATION
(Continued)

If LTD is $\leqq 20$ then the model uses the negative binomial distribution. Otherwise, the Laplace distribution is used. While the negative binomial is more cumbersome to use than the Laplace, simulation studies indicated that it was better for low demand items than the Laplace.

If the negative binomial is used, the model computes the theoretical optimum reorder point and backs into a safety level by subtracting out *LTD*. *SL* is computed directly from a *closed form* expression when the Laplace is used. Again, refer to "Evaluation of Several VSL/EOQ Models" by IRO for details. Safety level is constrained by the model so that $0 \leqq SL \leqq$ minimum (LTD, 3σ).

The safety level is output (virtually) directly by the model and becomes part of the reorder warning point.

ARMY IMPLEMENTATION OF VSL/EOQ POLICIES

REQUIREMENTS DETERMINATION (CONTINUED)

o ECONOMIC REPAIR QUANTITY (ERQ)

- oo NO MODEL FOR COMPUTING ERQ
- oo AN ACCUMULATION TIME MAY BE ADDED TO THE REPAIR CYCLE AND IS MEANT TO BE THE TIME NEEDED TO ACCUMULATE AN' ERQ's WORTH OF UNSERVICEABLES
  - ooo CAN BE DONE ONLY IF THERE IS A SIGNIFICANT SET-UP COST
  - ooo MOST SECONDARY ITEM REPAIR IS A JOB SHOP OPERATION
- oo ARMY IS CURRENTLY MODIFYING σ COMPUTATION TO INCLUDE PROLT VARIABILITY

Slide #22

REQUIREMENTS DETERMINATION
(Continued)

The Army has no model for computing economic repair quantities, although an accumulation time may be added to the repair cycle. The accumulation time is meant to be the time it takes to accumulate an economic batch for repair. Presently, the Army's position is that most secondary item repair is of the job-shop type and incurs relatively little set up cost. Only items which can be shown to have large set up cost are eligible to have an accumulation time. accumulation times are set by the overhaul facility.

It was noted earlier that lead time variability is not a factor in requirements computation. There is, however, a change under way to incorporate lead time variability, and is expected to be implemented by April 80. Studies by the Army indicate that introducing lead time variability is only marginally effective unless the DoD Instruction 4140.39 Safety Level constraint is relaxed. If the SL constraint is changed to require only that $SL \leq 3\sigma$, then introducing lead time variability gives a significant improvement in effectiveness.

ARMY IMPLEMENTATION OF VSL/EOQ POLICIES

ESSENTIALITY

- ESSENTIALITY IS NOT USED TO AFFECT VSL/EOQ COMPUTATION DIRECTLY AS PERMITTED BY DODI 4140.39

- DEMAND ACCOMODATION IS ADJUSTED TO REFLECT OPERATIONAL READINESS TARGETS FOR WEAPON SYSTEM. SEE DISCUSSION ON WHAT TO STOCK POLICY.

Slide #23

ESSENTIALITY

The Army does not use essentiality in its VSL/EOQ computation as permitted by DoD Instruction 4140.39. All factors now are implicity set to 1 within the VSL/EOQ model.

When using the COSDIF model to determine what items to stock, there is some consideration given to weapon system criticality. As noted earlier COSDIF parameters are set so that the expected accomodation is equal to the operational readiness target for the weapon system. There is, however, no consideration given to differences in criticality of items used in the system.

ARMY IMPLEMENTATION OF VSL/EOQ POLICIES

IMPLEMENTATION ASSUMPTIONS

- o RECONCILIATION OF DODI 4140.39 MODEL WITH ARMY CONCEPT OF DEMAND FORECASTING
  - oo DODI 4140.39 ASSUMES MEAN DEMAND RATE IS KNOWN AND CONSTANT WHEREAS ARMY DEMAND FORECASTS ARE GENERALLY TIME DEPENDENT
  - oo DEMAND RATE FED TO MODEL IS AN AVERAGE OF THE FORECASTED BASE DEMANDS PLUS OVERHAUL DEMANDS
    - ooo THESE DEMANDS ARE CONSIDERED UNCERTAIN AND IN NEED OF A SAFETY LEVEL
    - ooo NOT STRICTLY APPROPRIATE FOR COMPUTING EOQ, BUT THESE DEMANDS USUALLY CONSTITUTE MOST OF THE FORECASTED DEMANDS FOR AN ITEM
  - oo MODEL COMPUTED SL IS USED AS IS
  - oo MODEL COMPUTED EOQ IS CONVERTED TO MONTHS AND APPLIED TO ALL FORECASTED DEMANDS AND RETURNS

Slide #24

IMPLEMENTATION ASSUMPTIONS

Because the assumptions of the DoD Instruction 4140.39 model differ from those of the Army system, there were several areas where the DoD Instruction 4140.39 model had to be reconciled with the system.

As discussed earlier, the Army produces a time phased schedule of demand forecasts, and forecasts the different types of demand separately. The DoD Instruction 4140.39 model on the other hand, assumes that the demand rate is constant over time. Moreover, DoD Instruction 4140.39 implies that recurring and overhaul demands should constitute the demand rate. Other non-recurring requirements are to be added in afterwards. Consequently, the Army constructs a demand rate for the VSL/EOQ model by averaging the base demands and overhaul demands over an estimate of the Requirement Objective Period (The current RO period is used). These are the demands considered random and in need of a safety level. However, this AMD is not strictly correct for computing the EOQ. All demands should be accounted for in EOQ computations. Neverthless, base demands plus overhaul demands usually constitute most of the demand for an item so this is not felt to cause great error. Moreover SL is used directly whereas the total forecasted demands and returns are applied to the procurement cycle to get the procurement cycle quantity.

ARMY IMPLEMENTATION OF VSL/EOQ POLICIES

IMPLEMENTATION ASSUMTIONS (CONTINUED)

- o RECONCILIATION OF DODI 4140.39 MODEL WITH ONE-MONTH REVIEW CYCLE
  - oo REQUIREMENTS DETERMINATION TIME OF ½ MONTH IS ADDED TO ALT
- o SAFETY LEVEL COMPUTATION WHEN PROCUREMENT QUANTITY IS DELIVERED IN PHASES
  - oo REAL EFFECT OF PROCUREMENT QUANTITY ON SUPPLY PERFORMANCE IS DETERMINED BY DELIVERY QUANTITIES
  - oo SL SHOULD REFLECT THE EFFECT OF MULTIPLE DELIVERIES
  - oo SL IS COMPUTED USING THE DELIVERY CYCLE QUANTITY IN TVC INSTEAD OF EOQ

Slide #25

IMPLEMENTATION ASSUMPTIONS
(Continued)

Presently, the Army system is capable of making reorder point checks only once per month. Thus, when it is recognized that a reorder point has been reached the item has, on the average, been subjected to an additional ½ month of demand since the reorder point was actually hit. To correct for this, the Army adds ½ month to the ALT when computing the reorder point. This ½ month is also reflected in the SL.

Many of the higher dollar value items are delivered in increments of the procurement quantity. When this is done, it incorrect to use the backorder expression of the DoD Instruction 4140.39 model which assumes that the whole quantity is delivered at one time. Since the amount delivered is an important determinant of supply performance-in this case time weighted requisitions short-the SL is computed in the Army model using the deliver quantity in place the EOQ.

ARMY IMPLEMENTATION OF VSL/EOQ POLICIES

GOALS FOR USAGE OF MODELS

- o STOCKED ITEM LIST IS KEYED TO OPERATIONAL READINESS TARGET FOR WEAPON SYSTEM
  - oo ACCOMODATION GOAL = OPERATIONAL READINESS GOAL
    - ooo DOES NOT WORK WELL FOR LOW DENSITY SYSTEMS
  - oo SHORTAGE COST PARAMETER IN COSDIF MODEL IS ADJUSTED TO MEET TARGET
- o STOCK AVAILABILITY GOAL IS 85%
  - oo STOCK AVAILABILITY IS PERCENT OF REQUISITIONS FILLED IN TCTAL IMMEDIATELY
  - oo SHORTAGE COST IN VSL/EOQ MODEL IS ADJUSTED AND CURVES OF PROBABILITY THAT AT LEAST ONE UNIT IN A REQUISITION WILL BE FILLED IMMEDIATELY VERSUS THE SHORAGE COST PARAMETER ARE PRODUCED

Slide #26

GOALS FOR USAGE OF MODELS

In order to determine the items to be stocked, the Army uses a heuristic procedure which sets demand accommodation to a goal equal to the Operational Readiness goal for a weapon system. Operational Readiness is basically the percent of time a weapon system is able to perform its mission. Demand accommodation is the fraction of demands for stocked items and, in this case, is measured over all demands for items used on the given weapon system. To achieve the target, the shortage cost parameter in the COSDIF model is varied until the goal is achieved. For low density high operational capability systems the approach breaks down. Virtually every item needs to be stocked to achieve the demand accommodation goal, and an absurd value of the shortage cost parameter is needed. Thus, for these type systems, the Army relies on NSO_2 type stockage.

The performance goal for stocked items is 85% supply availability. Supply availability is the percent of requistions for stocked items which are filled, in total, immediately. Partial fills do not count. As with the COSDIF model, the shortage cost parameter is varied within the VSL/EOQ model until the goal is achieved. The DoD Instruction 4140.39 model is used to estimate supply availability here. There is no simulation with real demand history.

ARMY IMPLEMENTATION OF VSL/EOQ POLICIES

GOALS FOR USAGE OF MODELS (CONTINUED)

- STOCK AVAILABILITY (CONTINUED)
  - SHORTAGE COST PARAMETERS SELECTED FOR EACH ICP WITH INTENT OF ACHIEVING 85% STOCK AVAILABILITY AT EACH ICP
  - UPDATES OF SHORTAGE COST PARAMETERS HAVE BEEN IRREGULAR SINCE DODI 4140.39 WAS IMPLEMENTED
  - SUPPLY PERFORMANCE ANALYZER IS AVAILABLE TO ICP's FOR ADJUSTING SHORTAGE COST BUT HAS NOT BEEN USED

Slide #27

GOALS FOR USAGE OF MODELS
(Continued)

The shortage cost parameters are set for each ICP with the intent of achieving 85% availability for stock fund and 85% for appropriation items.

Since DoD Instruction 4140.39 has been implemented, the shortage parameters have been updated infrequently and irregularly. The ICP's have been provided with a Supply Performance Analyzer which runs in conjunction with the budget stratification system. However, the SPA has not been used as intended.

ARMY IMPLEMENTATION OF VSL/EOQ POLICIES

PARAMETERS AND CONSTRAINTS

- o SHELF LIFE
  - oo IF STOCKAGE OBJECTIVE EXCEEDS SHELF LIFE, PROCUREMENT CYCLE AND THEN SAFETY LEVEL ARE REDUCED TO BRING RO DOWN TO SHELF LIFE
    - ooo REORDER CYCLE AND SL NOT REDUCED BELOW 3 MONTHS AND O RESPECTIVELY
- o PHASE-OUT DATE
  - oo LIKE SHELF LIFE EXCEPT SL IS REDUCED FIRST
  - oo OBSOLESCENCE RATE AND PROCUREMENT COSTS ARE COMPUTED ACCORDING TO DODI 4140.39 INSTRUCTIONS

Slide #28

PARAMETERS AND CONSTRAINTS

In addition to the constraints on Safety Levels and Order Quantities imposed by DoD Instruction 4140.39, the Army further constrains its levels depending on the shelf life of the item and the item's phase out date. If the average time stock is on hand it is expected to exceed the shelf life, then first the procurement cycle is reduced, and then the safety level until the expected time on hand equals the shelf life. However, the SL is not reduced below zero, and the procurement cycle is not reduced below 3 months.

A similar procedure is used for the phase out date. The Requirements Objective is compared to the Phase Out date. SL first, and the procurement cycle are reduced to bring the RO down to the Phase Out date.

The Obsolescence Rate and Procurement Costs are computed in accordance with DoD Instruction 4140.39. However, the Army has recently computed new obsolescence rates which seem quite low and is probably due to the low amount of recent disposals. A new look should be taken at the methodology for computing obsolescence.

ARMY IMPLEMENTATION OF VSL/EOQ POLICIES

SENSITIVITY OF PARAMETERS AND CONSTRAINTS

o PRESENT DODI 4140.39 SL CONSTRAINTS ARE TOO RESTRICTIVE SL, WHEN CONSTRAINED, IS VIRTUALLY ALWAYS LIMITED BY PLT DEMAND

o LEVEL INSTABILITY

  oo PARAMETERS THEMSELVES ARE UNSTABLE

    ooo e.g., UNIT PRICE, OBSOLESCENCE RATE, BASE AMD

  oo PROCUREMENT COST BOUNDARIES CAUSE INSTABILITY

  oo ARMY IS BEGINNING A STUDY TO INVESTIGATE EXTENT AND CAUSES

Slide #29

SENSITIVITY OF PARAMETERS AND CONSTRAINTS

The Army has been experiencing two problems with sensitivity of the model. Recent investigation into improvement of the model revealed that the constraint which limits SL to no more than the expected procurement lead time demand is frequently active, and usually quite restrictive since an expected procurement lead time of demand is often less than one standard deviation of lead time demand. The Army is requesting that OSD relax the safety level constraint so that the only constraint is three standard deviations of lead time demand.

Recently, there have been complaints from Army ICP's that their stockage levels are unstable. This however, seems to be caused by the instability of the inputs to the model. In particular unit price and average monthly demand. A study is beginning to investigate the extent of the problem.

ARMY IMPLEMENTATION OF VSL/EOQ POLICIES

PROBLEM AREAS IN IMPLEMENTATION AND USE OF MODELS

- ACCEPTANCE OF DODI 4140.39 PERFORMANCE GOAL WITH ABSENCE OF ESSENTIALITY FACTORS
- SL CONSTRAINT TOO SEVERE
- METHODOLOGY FOR COMPUTING OBSOLESCENCE RATE
- COORDINATING COMPUTED EOQ WITH ACTUAL BUY QUANTITY
- FORECASTING UNIT PRICE
- QUANTITY DISCOUNT PROCEDURES

Slide #30

PROBLEM AREAS IN IMPLEMENTATION & USE OF MODELS

On this chart are listed some problems associated with the DoD Instruction 4140.39 VSL/ EOQ model. Some of these, i.e. restrictive SL constraint and methodology for computing obsolescence rate, have been discussed elsewhere of the rest, only the problem of getting the DoD Instruction's supply performance objective accepted by the ICP's is inherent to the model. The others are problems which would exist with any stockage model.

3.0 AIR FORCE DOCUMENTATION OF VSL/EOQ IMPLEMENTATION

AIR FORCE IMPLEMENTATION

OF

VSL/EOQ POLICIES

FOR

CONSUMABLE ITEMS

AF IMPLEMENTATION OF VSL/EOQ POLICIES

DATA COLLECTION SYSTEM

REQUISITION PROCESSING SYSTEM

- o CENTRAL CONTROLLED ISSUES TO CUSTOMERS
- o WEEKLY TRANSACTION REPORTING
- o OBSERVATIONS COLLECTED
  - oo RECURRING DEMAND UNITS
  - oo RECURRING DEMAND FREQUENCIES
  - oo NONRECURRING DEMAND UNITS
  - oo SERVICEABLE RETURN UNITS
- o TWO YEAR BASE PERIOD
  - oo QUARTERLY INCREMENTS

Slide #2

The requisition processing system is the primary source of data used in the mechanized requirements computation for consumable items.

All wholesale issues to customers are centrally controlled at the respective ICPs (inventory control points) and data are updated in requirements system by weekly transaction reporting. Errors to these data are corrected manually by the Item Manager (IM).

Observations collected are: recurring demand units, recurring demand frequencies, non-recurring demand units and serviceable return units.

A two year history of these data are maintained in quarterly increments.

AF IMPLEMENTATION OF VSL/EOQ POLICIES

DATA COLLECTION SYSTEM

PROCUREMENT HISTORY SYSTEM

- OBSERVATIONS COLLECTED
  - ADMINISTRATIVE LEADTIME
  - PRODUCTION LEADTIME
  - UNIT PRICE
- UPDATE FREQUENCY
  - ADMINISTRATIVE LEADTIME (MANUAL) AS OCCURS
  - PRODUCTION LEADTIME (MANUAL) AS OCCURS
  - UNIT PRICE ANNUALLY (LATEST BUY)

Slide #3

The procurement history system is the source of the other data: administrative leadtime, production leadtime and unit price. Leadtimes are updated in the requirements system manually by the IM whenever changes occur. The unit price is updated mechanically on an annual basis.

AF IMPLEMENTATION OF VSL/EOQ POLICIES

FORECASTING

CATEGORIZATION

GROUPING CODE	X	T	P	M
$ VALUE AV. ANNUAL DEMAND	≦ 500	> 500 ≦ 5000	> 5000 ≦ 50000	> 50000
FORECASTING FREQUENCY	MONTHLY	4 TIMES MONTH	4 TIMES MONTH	4 TIMES MONTH
DEMAND RATE	RECURRING PLUS NON RECURRING DEMANDS	RECURRING PLUS NON RECURRING DEMANDS	RECURRING DEMANDS MINUS SERVICEABLE RETURNS	RECURRING DEMANDS MINUS SERVICEABLE RETURNS

Slide #4

Consumable items are categorized by dollar value of average annual demands for purposes of determining forecasting frequency, type of demand rate to be used and management intensity.

AF IMPLEMENTATION OF VSL/EOQ POLICIES

FORECASTING

- o DEMAND RATE
  - oo BASED ON SINGLE MOVING AVERAGE
  - oo PROGRAM RELATED ON SELECTIVE BASIS
- o LEADTIME (LT)
  - oo FORECASTS BASED ON LATEST LEADTIME EXPERIENCED OR CONTRACTOR QUOTE
  - oo LT REQUIREMENT = LT DAYS X DAILY DEMAND RATE

Slide #5

The demand rate forecast is based on a single moving average of the past two years' demands. The IM can code an item to use only the past one year's demands when an item is in a trend. Demand rates are adjusted by program factors on a selective basis. This is done primarily on items applicable to aircraft, with increasing or decreasing flying hour programs.

Leadtime forecasts are based upon latest leadtime or contractor quotes. The *requirement is computed in days*.

AF IMPLEMENTATION OF VSL/EOQ POLICIES

FORECASTING

- o DISTRIBUTION OF LEADTIME DEMANDS
  - oo LAPLACE DISTRIBUTION
  - oo ABSOLUTE DEVIATION DEMANDS IN EACH QUARTER = QUARTERLY NET RECURRING DEMANDS - (3XMDR)
  - oo MEAN ABSOLUTE DEVIATION (MAD) DEMANDS OVER BASE PERIOD =

$$\Sigma \frac{\text{ABSOLUTE DEVIATIONS/QTR}}{\text{BASE PERIOD QTRS}}$$

  - oo STANDARD DEVIATION LEADTIME DEMANDS = .5945MAD X (.82375 + .42625 LEADTIME MONTHS)
  - oo CONSTANT .5945 CONVERTS QUARTERLY MAD TO MONTHLY MAD
  - oo CONSTANTS .82375 AND .42625 EXPRESS MAD OVER LEADTIME AND RECOGNIZE INFLUENCE OF PREVIOUS MONTH'S DMDS

Slide #6

The distribution of leadtime demand observations is assumed to fit a Laplace distribution. The standard deviation of leadtime demand is computed by first determining the absolute deviation of demands for quarterly observations in the forecasting base period. The absolute deviation of demands in each quarter is the quarterly net recurring demand observation minus three times the monthly demand rate forecast. The mean absolute deviation (MAD) of demands over the forecasting base period is the sum of the absolute deviations in each quarter of the base period divided by the number of quarters in the base period. This MAD and the leadtime forecast (in months) are coupled via the formula shown here to obtain the standard deviation of leadtime demands.

AF IMPLEMENTATION OF VSL/EOQ POLICIES

PROGRAM DATA

- FLYING HOUR PROGRAMS
  - MECHANIZED
  - RATIO BY AIRCRAFT = $\frac{\text{PROJECTED YEARS FLYING HOURS}}{\text{PAST YEARS FLYING HOURS}}$
  - USED TO FACTOR COMPUTED DEMAND RATE FOR ITEMS PECULIAR TO GIVEN AIRCRAFT
  - RATIO USED WHEN 15% INCREASE OR 10% DECREASE
- DEPOT REPAIR PROGRAMS
  - MANUAL
  - USED WITH REPLACEMENT FACTOR TO COMPUTE REPAIR REQUIREMENTS
  - COMPARED TO DEMAND BASED REQUIREMENT AND DIFFERENCE USED AS ADDITIVE

Slide #7

The requirements system has a mechanized capability to use program data. Flying hour program ratios are computed by HQ AFLC and used to factor the computed demand rate for items peculiar to a given aircraft. Currently, these ratios are used when they reflect a 15% increase or a 10% decrease in the flying hour programs.

Manual program related computations are made on items applicable to end items with large depot repair programs. The manual computations are based upon projected repair programs and item replacement factors. The difference between the program related and demand based requirements is used as an additive in the requirements computation.

AF IMPLEMENTATION OF VSL/EOQ POLICIES

ASSUMPTIONS

- CONSTANT AVERAGE DEMAND
- INVENTORY SUPPLY LEVELS DO NOT CHANGE
- LAPLACE DISTRIBUTION OF DEMANDS
- NO OVERSHOOT OF REORDER LEVEL
- CONSTANT LEADTIMES
- ACCURATE BOOK INVENTORY
- NO BACKORDERS UNTIL ON HAND ASSETS DEPLETED
- ZERO DEMAND HISTORY IMPLIES NO FUTURE DEMANDS

Slide #8

The model used in VSL/EOQ computations embodies the assumptions shown here. As seen, the model assumes a steady state environment (i.e., constant average demand, constant inventory levels, constant leadtimes). In addition, the model assumes leadtime demand observations as distributed in accordance with a Laplace probability distribution; a continuous review situation and continuous demand (i.e., no overshoot of reorder level); accurate asset reporting; no reservation or rationing of assets (i.e., no backorders until on-hand assets depleted); and a history of zero demands implies a zero demand forecast.

AF IMPLEMENTATION OF VSL/EOQ POLICIES

GOALS FOR USAGE OF MODELS

- o MAINTAIN DOLLAR VALUE SAFETY LEVEL AT EACH ICP = $55 DAYS ICPs DEMANDS
- o SHORTAGE COST DETERMINED BY INTERPOLATION
- o NO SIMULATION CAPABILITY

Slide #9

The current budget formulation and execution goal is to maintain a safety level at each ICP equal to the dollar value of 55 days of the ICP's demands. The shortage cost at each ICP is determined by interpolation to achieve this goal.

The Air Force has been limited to this type of goal because of the lack of simulation capability. The simulation that was developed when Air Force implemented the VSL model was very inaccurate in terms of predicting fill rates. Air Force is working on a new simulator and expects to have it operational by September 1980.

AF IMPLEMENTATION OF VSL/EOQ POLICIES

PARAMETERS AND CONSTRAINTS

- o COST TO ORDER
  - oo 1975 STUDY
  - oo UPDATED ANNUALLY BY GS CIVILIAN WAGE INCREASED

ICP	SMALL PURCHASE	NEGOTIATED PURCHSE
OC	$308.16	$628.28
OO	361.10	708.92
SA	283.15	498.48
SM	365.85	473.35
WR	312.25	471.94

Slide #10

The cost to order is based on studies made in 1975. These costs are updated annually by the respective ICPs for the percent of civilian wage increases. The current values are shown here. The ICPs are: OC, Oklahoma City; OO, Ogden; SA, San Antonio; SM, Sacremento; WR, Warner-Robbins.

AF IMPLEMENTATION OF VSL/EOQ POLICIES

PARAMETERS AND CONSTRAINTS

- o COST TO HOLD
  - oo OPPORTUNITY COST 10%
  - oo STORAGE COST 1%
  - oo OBSOLESCENCE UPDATED ANNUALLY BASED ON PAST 3 YEARS DATA

ICP	OBSOLESCENCE
OC	4%
OO	8%
SA	6%
SM	8%
WR	11%

Slide #11

In determining holding costs, AF uses 10% for opportunity cost and 1% for storage cost. The obsolescence rate is updated annually based on the past 3 years' data and accounts for actual disposals plus changes to stratified potential excess. The obsolescence rate varies by ICP as shown here.

AF IMPLEMENTATION OF VSL/EOQ POLICIES

PROBLEM AREAS

- o SIMULATION
  - oo PREDICTION OF SUPPORT MEASURES
- o AVERAGE REQUISITION SIZE

Slide #12

Primary problems Air Force has had in implementing the *VSL* model are the lack of an accurate simulator (supply performance analyzer) and errors in data used to compute the average requisition size.

AF IMPLEMENTATION OF VSL/EOQ POLICIES

REQUIREMENTS DETERMINATION FORMULAS DERIVATION

- MODEL EXPLAINED IN AFLC OPERATIONS ANALYSIS TECHNICAL MEMORANDUM NO. 9 OF JANUARY 1970, "MORE ADO ABOUT EOQ".
- SINGLE-ECHELON, MULTI-ITEM, CONTINUOUS REVIEW, STEADY STATE SYSTEM
- BASIS IS TVC OF DODI 4140.39
- PROBABILITY DENSITY FUNCTION OF LEADTIME DEMAND; NO NEGATIVE SAFETY LEVELS PERMITTED

$$F(X) = \frac{\sqrt{2}}{2\sigma} \exp\left(-\sqrt{2} \left(\frac{X-\mu}{\sigma}\right) \right)$$

- INCORPORATING THE PROBABILITY DENSITY FUNCTION INTO DODI 4140.39 MODEL AND MINIMIZING TVC YIELDS

$$K = \frac{1}{\sqrt{2}} \ln \left[\frac{(0.5)(\lambda)(E)(\sigma)[1-\exp(-\sqrt{2}\frac{Q}{\sigma})]}{(\sqrt{2})(Q)(I)(C)(S)} \right]$$

AND SAFETY LEVEL = $K'\sigma$
IF $K<0$, K' IS SET TO ZERO

AF IMPLEMENTATION OF VSL/EOQ POLICIES

REQUIREMENTS DETERMINATION FORMULAS DERIVATION
(CONTINUED)

$$\sqrt{\frac{2AD}{IC}} \leqq Q \leqq \frac{\sigma}{\sqrt{2}} + \sqrt{\frac{2AD}{IC} + \frac{\sigma^2}{2}}$$

- APPROXIMATIONS/MODIFICATIONS APPROVED BY OSD

$$E = \sqrt{S}$$

$$Q = \min\left\{3D,\ \max\left(\sqrt{\frac{2AD}{IC}},\ \frac{D}{2}\right)\right\}$$

$$K' = \min\left\{\left[\frac{LTD}{\sigma},\ 3\right],\ \max[K,0]\right\}$$

WHERE K IS:

$$\frac{1}{\sqrt{2}} \quad \ln \left[\frac{0.5\lambda\sigma\left[1-\exp\left(-\frac{\sqrt{2}Q}{\sigma}\right)\right]}{\sqrt{2}\ Q\ IC\ \sqrt{S}} \right]$$

λ IS SET SO $\Sigma\ K'_i\ \sigma_i\ C_i < \emptyset\ \Sigma\ D_i\ C_i$

Slide #13 & 14

The VSL model implemented by the Air Force is explained and derived in the AFLC publication "More Ado About EOQ", AFLC Operations Analysis Technical Memorandum No. 9 of January 1970. The derivation is basically as shown here and includes the basic assumptions embodied in the DODI 4140.39 TVC (Total Variable Cost) equation.

A key underlying assumption which leads to the derivation used by the Air Force, DLA and Army is that leadtime demands are distributed in accordance with the Laplace probability distribution. The density function of the distribution is shown here. When that distribution is incorporated into the DODI 4140.39 TVC and the Method of *Lagrange is applied, one can obtain a closed form* solution (for a given Q) for the number of standard deviations (K) of leadtime demand represented by the safety level. Note that if the computation results in a negative value for K, then K is constrained to zero.

Furthermore, the optimal order quantity (Q) lies between the familiar Wilson EOQ and an upper bound which is highly dependent on the magnitude of the standard deviation of leadtime demand. For simplicity, Air Force utilizes the Wilson EOQ formula for the basic computation and constrains it to the range of 6 months demand to 3 years demand.

Pending the establishment of an essentiality system for use in the VSL model, Air Force has received OASD(MRA&L) approval to use the square root of the average requisition size in place of essentiality, to cushion the impact of the average requisition size on the magnitude of the safety level.

AIR FORCE IMPLEMENTATION

OF

VSL FOR REPARABLES

AD-A102 147 ASSISTANT SECRETARY OF DEFENSE (MANPOWER RESERVE AFFA--ETC F/G 5/1
STOCKAGE POLICY ANALYSIS. ANNEX A. COMPONENT DOCUMENTATION OF D--ETC(U)
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AIR FORCE IMPLEMENTATION OF VSL FOR REPAIRABLES

Slide #1

This presentation covers the Air Force mechanized recoverable item requirements computation system (D041 and D041A).

These data systems compute worldwide needs for recoverable spares buy and repair quantities which are funded for procurement out of investment appropriations and funded for depot level repairs through the exchangeable spares portion of the depot purchased equipment maintenance (DPEM) program.

AIR FORCE IMPLEMENTATION OF VSL FOR REPARABLES

ORDER OF TOPICS

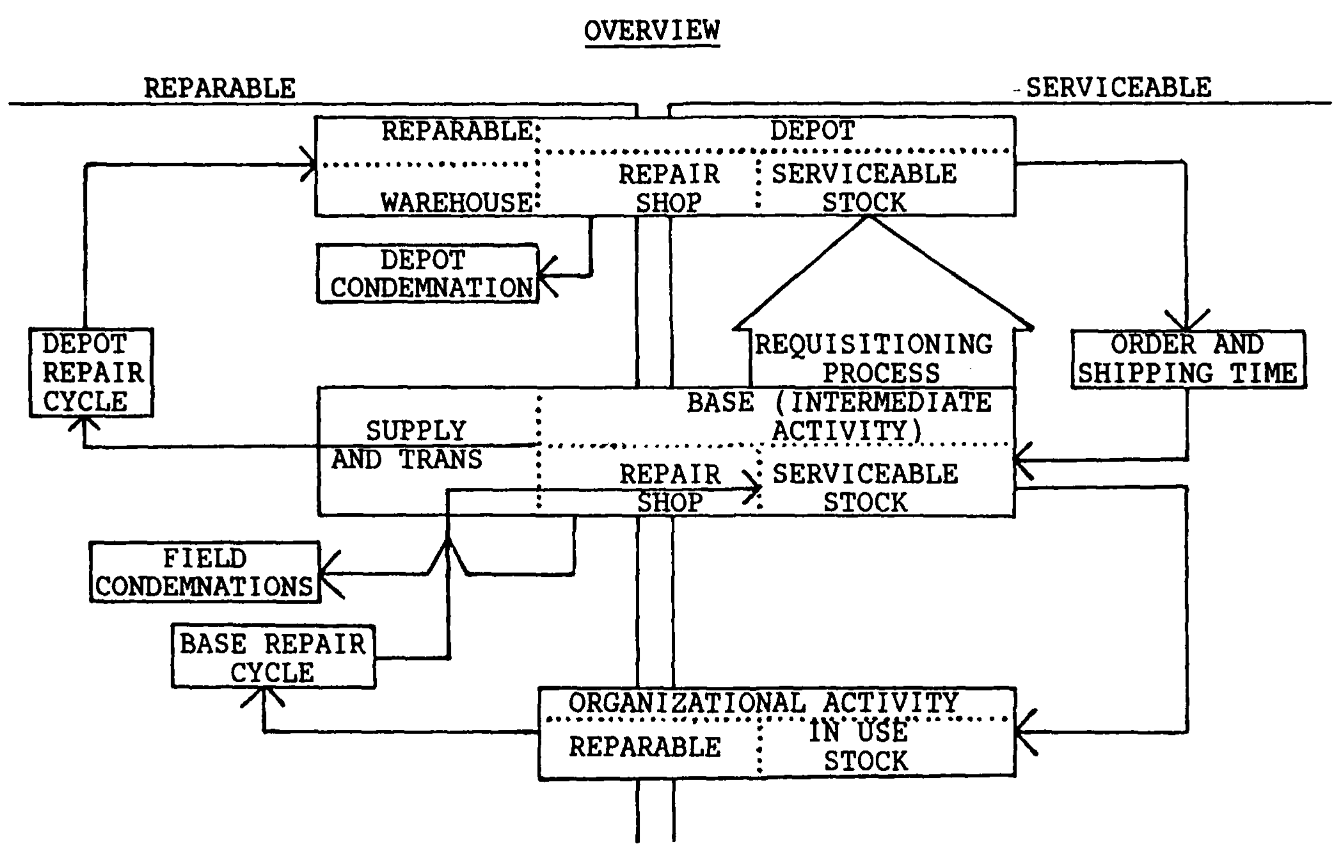
- OVERVIEW
- DATA COLLECTION SYSTEM
- FORECASTING
- REQUIREMENTS DETERMINATION FORMULAS DERIVATION
- PROGRAM DATA
- ESSENTIALITY
- IMPLEMENTATION ASSUMPTIONS
- GOALS FOR USAGE OF MODELS
- PARAMETERS AND CONSTRAINTS
- SENSITIVITY OF PARAMETERS AND CONSTRAINTS
- PROBLEM AREAS IN IMPLEMENTATION AND USE OF MODELS
- RECOMMENDATIONS FOR LONG TERM FOLLOW-ON EFFORT

AIR FORCE IMPLEMENTATION OF VSL FOR REPAIRABLES

Slide #2

This is the order of topics:

AIR FORCE IMPLEMENTATION OF VSL FOR REPARABLES



AIR FORCE IMPLEMENTATION OF VSL FOR REPAIRABLES

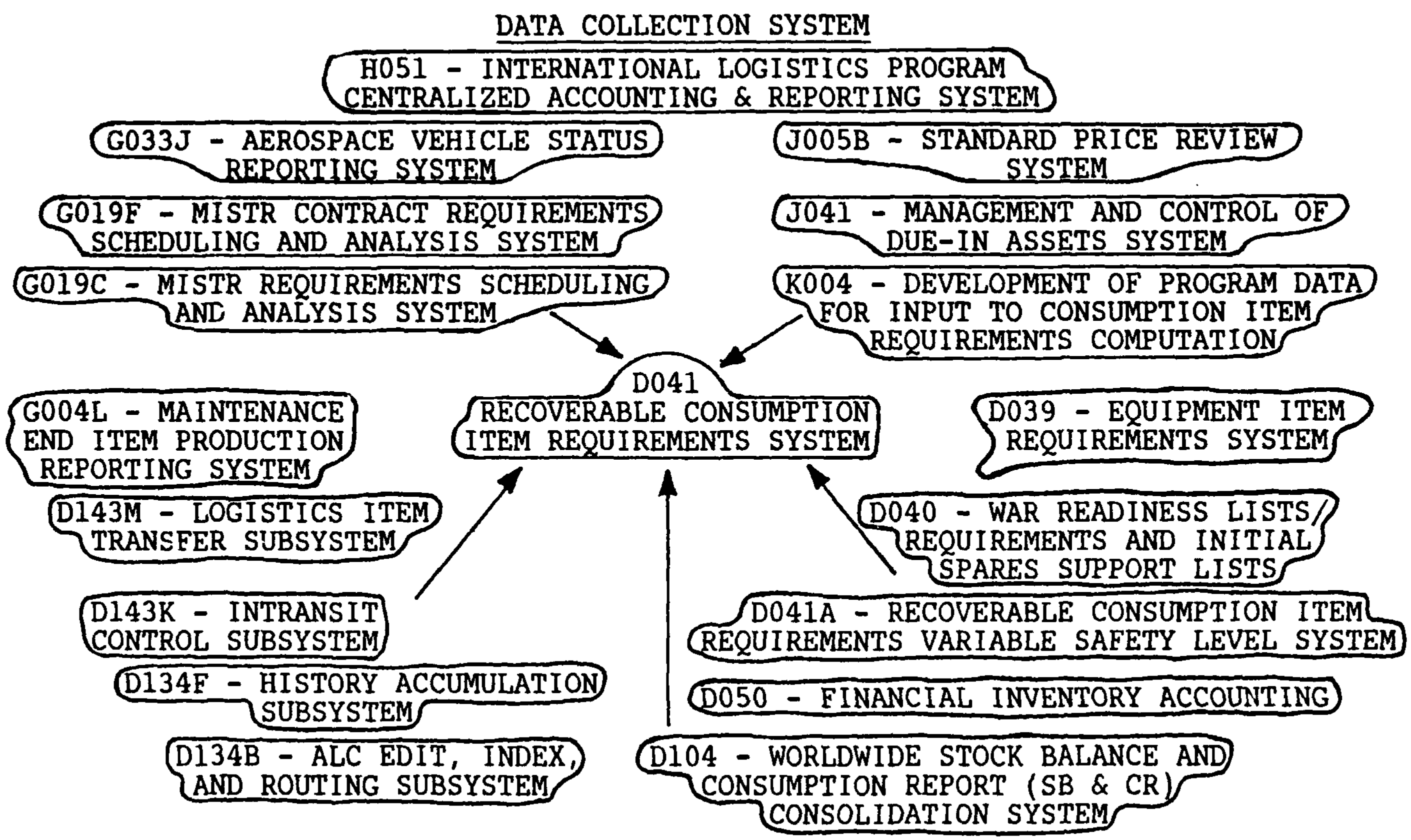
Slide #3

OVERVIEW

This is the flow of the two-echelon, base-depot operation system model. Consider the organizational activity, for example an aircraft squadron, to be at the base. There are actually 3 levels of maintenance - organizational maintenance, intermediate maintenance, and depot-level maintenance. Organizational and intermediate maintenance, however, are both considered base-level.

If a reparable generates at the organizational activity, it goes through the repair cycle at the organizational activity and if it can't be repaired there, goes to the repair shop at the base where it is repaired and returned to serviceable stock where it can be requisitioned by the organizational activity. If the base can't repair the item, it may condemn it or send it to the depot for repair. The depot either condemns it or repairs it and returns it to serviceable stock where it can be requisitioned by the base.

AIR FORCE IMPLEMENTATION OF VSL FOR REPARABLES



AIR FORCE IMPLEMENTATION OF VSL FOR REPAIRABLES

Slide #4

DATA COLLECTION SYSTEM

The DO41 System, as a model of the total logistics spectrum, requires input data from numerous sources. The system receives data from manual inputs and mechanical sources. Interfacing automated data sources are outlined on this chart. (clockwise from the right).

Data are received from these systems quarterly, except for the DO39 system, for use in computing requirements. The input data have the same cutoff dates as the DO41 system's computation cycles: 30 June, 30 September, 31 December, and 31 March. The interfacing systems' data are usually available for DO41 use approximately 25 to 30 days subsequent to the applicable cutoff dates.

The DO39, Equipment *Item* Requirements Systems, *produces* and distributes equipment item programs to the ALC having prime responsibility for component spares. These programs are used as the basis for computing requirements for recoverable items that have equipment items as their application. The data is produced semiannually with the results of the DO39 October computation used in the 31 December DO41 cycle and results of the DO39 April computation used in the 31 March DO41 cycle.

The DO40, War Readiness Lists, provide war reserve materiel prepositioned requirements and high priority mission support kit (HPMSK) requirements, i.e., war readiness spares kits (WRSK) and base level self sufficiency (BLSS).

AIR FORCE IMPLEMENTATION OF VSL FOR REPAIRABLES

Slide #4

DATA COLLECTION SYSTEM
(Continued)

The input file from the D041A, Variable Safety Level (VSL) System, contains base and depot safety level requirements. Although the total stock level is computed by the D041A, only the safety level portion is passed to the D041.

The D050, Financial Inventory Accounting (FIA) System, provides FIA asset gains and losses transactions (dollar value) and is used to compare past to projected issues and receipts for the developement of budget submissions and for analysis of dollar values of transactions.

The D104, Stock Balance and Consumption Reporting System, provides base and depot level usage data and worldwide asset data: assets, usage, due out to maintenance (DOTM) requirements (an item which has failed and been pulled off the aircraft), and number of users. The usage data is the basis for factor development in the D041 system and the asset data is the only on-hand asset data available for use in developing requirements.

The D143B, Edit, Index, and Routing Subsystem, provides stock numbers and associated catalog management data, manufacturer's part numbers, and manufacturer's codes (e.g., noun, price, item manager code).

The D143F, History Accumulation Subsystem, provides base repair cycle days as experienced by individual bases. This information is used to develop our base repair cycle requirement.

Slide #4

DATA COLLECTION SYSTEM
(Continued)

The D143K, Intransit Control Subsystem, provides base order and shipping time days and reparable intransit days. The latter is used in developing the depot repair cycle time. Both are addressed in the "Formulas Derivation" section.

The D143M, Logistics Item Transfer Subsystem, provides the individual requirements system at each Air Logistics Center (ALC) with the data on items for which management responsibility has transferred from one ALC to another. Item data is extracted from the losing ALC and received by the gaining ALC.

The G004L, Maintenance End Item Production Reporting System, provides actual organic depot overhaul repaired quantities and the orgainic depot overhaul condemned quantities.

The G019C, Management of Items Subject to Repair (MISTR) Requirements Scheduling and Analysis System, provides unit repair cost, unit repair man-hours, source-of-repair codes and percents, and shop flow days.

The G019F, MISTR Contract Requirements Scheduling and Analysis System, provides contractor depot overhaul repaired and condemned quantities. Both the G019 systems are used in developing the repair index of action and the repair central secondary item stratification.

Slide #4

DATA COLLECTION SYSTEM
(Continued)

The G033J, Aerospace Vehicle Status Reporting System, provides past program data by application number for Aircraft, missiles, drones, and engines. These are flying hour and inventory programs for a 30-month time period (D041 only needs 24 months of this).

The H051, International Logistics Program Centralized Accounting and Reporting System, inputs foreign military sales (FMS) cooperative logistics stock level case requirement quantities which are entered to the D041 as additive requirements.

The J005B, Standard Price Review System, provides the most current unit acquisition price based on the last purchase of the item.

The J041, Management and Control of Due-In Assets System, provides administrative and production lead time days and due-in assets, both serviceable and unserviceable. Assets are subtracted from the gross requirement to give a net requirement.

The K004, Development of Program Data for Input to Consumption Item Requirements Computation, provides projected future peacetime and wartime flying hour programs for aircraft, engines, missiles, and drones. These data are in quarterly increments for a 6-1/4 year projection plus retention (maximum of three years). The system is updated quarterly.

AIR FORCE IMPLEMENTATION OF VSL FOR REPAIRABLES

Slide #4

DATA COLLECTION SYSTEM

(Continued)

We can manually change every data element entering the D041 system at ICP level (file maintenance authorized) except:

National Stock Number
Expendability, Reliability, Recoverability Code
Unit of Issue
Past Programs
Future Programs
Financial Inventory Data
Interchangeability and Substitutability Groupings

AIR FORCE IMPLEMENTATION OF VSL FOR REPARABLES

FORECASTING

- BASIC COMPUTATION

PAST USAGE	÷	PAST PROGRAM	=	USAGE RATIO
G004L G019F D104		G033J		DEPOT OVERHAUL COND. % OIM DEMAND RATE BASE NRTS % BASE COND. %

USAGE RATIO	X	FUTURE PROGRAM	=	PROJECTED REQUIREMENT
		K004 D039		

- COMPUTED REQUIREMENT FILLS PIPELINE

  D143F - BASE REPAIR CYCLE DAYS

  D143K - ORDER AND SHIPPING TIME DAYS, REPARABLE INTRANSIT DAYS

  G019C - DEPOT REPAIR CYCLE DAYS

- BUY POINT

  J041 - ADMINISTRATIVE AND PRODUCTION LEADTIMES

Slide #5

FORECASTING

The D041 system uses 2 years of monthly item usage data divided by 2 years of monthly past program data - both moving averages - to compute a usage ratio or rate. For example, usage data from the G004L and the G019F systems are organic and contract depot overhaul required and condemned quantities which are used to compute the depot overhaul condemnation percent. The base reparable generations are provided by the D104 system and are used to compute the total Organizational Intermediate Maintenance (OIM) demand rate (failure rate). Base not-reparable-this-station (NRTS) and base condemnation quantities are also provided by this system to compute rates for each. The usage ratio is then multiplied by the projected future program for the aircraft, engine, missile, drone, or equipment end item that is the next higher assembly for the item. Rates may also be estimated by the equipment specialist if insufficient data is available, or a regression formula may be used if the program or usage data shows a trend.

Other systems contribute base repair cycle days (D143F), order and shipping time days and reparable intransit days (D143K), and depot repair cycle days (G019C). The requirement quantity is computed to fill the number of days in the base repair cycle, base order and shipping time (O&ST), and depot repair cycle pipelines. The point in time that the item must be bought to avoid gaps in the pipeline is determined according to the length of the administrative and production leadtimes from the J041 system.

AIR FORCE IMPLEMENTATION OF VSL FOR REPARABLES

<u>FORMULAS DERIVATION</u>

- D041A VS D041 SYSTEMS
- AFLC SUPPLY OBJECTIVE
- MARGINAL ANALYSIS

Slide #6

FORMULAS DERIVATION

This section discusses the derivation of the formulas used to compute the requirement. It covers these main topics.

AIR FORCE IMPLEMENTATION OF VSL FOR REPARABLES

FORMULAS DERIVATION

SAFETY = D041A REQUIREMENT - D041 PIPELINE REQUIREMENT

AIR FORCE IMPLEMENTATION OF VSL FOR REPAIRABLES

Slide #7

FORMULAS DERIVATION
(Continued)

The D041A system computes a stock level using the techniques that follow. This quantity is compared to the pipeline requirement computed by the D041 system discussed in the previous sections, and if it is larger, the difference becomes the safety level.

AIR FORCE IMPLEMENTATION OF VSL FOR REPARABLES

FORMULAS DERIVATION

AFLC SUPPLY OBJECTIVE:

MINIMIZE BASE LEVEL BACKORDERS

TECHNIQUE: MARGINAL ANALYSIS

BENEFITS: DRAMATICALLY REDUCE BACKORDERS AT NO INCREASE IN COST

OR

DRAMATICALLY REDUCE COST WITH NO INCREASE IN BACKORDERS

OR

REDUCE BACKORDERS, REDUCE COST

Slide #8

FORMULAS DERIVATION
(Continued)

As a result of various studies conducted both in-house and by the RAND Corporation in the latter part of the sixties, a measure of effectiveness, base-level backorders, for Air Force Logistics Command (AFLC) supply support was established with the corresponding objective being to minimize this measure. This measure and objective are applied to each recoverable item individually item by item.

The technique used to achieve the objective is called marginal analysis. Define marginal analysis as applying resources incrementally to achieve an objective, where the resource increments are as small as possible (or as feasible, or as practicable, or as any existing constraints permit) and are applied one increment at a time, each increment where it will "do the most good" toward achieving the objective. (The term "marginal analysis" comes from one early method of computing this analysis, where one or more tables of benefits achieved vs. resources expended were established, such that the benefit achieved per unit of resource expended appeared at the edges or "margins" of the tables.)

Applications of this technique can either dramatically reduce backorders from currently achieved levels at no increase in stockage policy costs, or dramatically reduce such costs without increasing base-level backorders, or achieve some combination of the reduced costs/reduced backorders benefits (but not as much of either of the two as in the first two extreme cases).

AIR FORCE IMPLEMENTATION OF VSL FOR REPARABLES

FORMULAS DERIVATION

- o MARGINAL ANALYSIS AND THE TWO-ECHELON MODEL
  - oo DEFINE BACKORDERS
  - oo FIND BACKORDERS FOR A BASE USING BASE RESUPPLY TIME
  - oo FIND BACKORDERS FOR MORE THAN 1 BASE
  - oo FIND INVENTORY LEVEL BY MINIMIZING THE COST EXPRESSION
  - oo AN EXAMPLE

Slide #9

FORMULAS DERIVATION
(Continued)

The mathematical logic which underlies the base and depot stock levels follows. First, define backorders in terms of stock on-hand, due-in, and due-out. Then find backorders for a single base using base resupply time; then find backorders for more than one base. Establish the inventory level by minimizing the cost expression. An example is also included in this section and another appears in "Parameters and Constraints".

AIR FORCE IMPLEMENTATION OF VSL FOR REPARABLES

FORMULAS DERIVATION

INVENTORY LEVEL = (ON-HAND) + (DUE-IN) - (BACKORDERS [DUE-OUT])

LET R = INVENTORY LEVEL

τ = CONSTANT RESUPPLY TIME

t = RANDOM POINT IN TIME

λ = DAILY DEMAND RATE

$P(X;\lambda T)$ = PROBABILITY OF X DEMANDS IN TIME INTERVAL OF LENGTH T

$B(R)$ = EXPECTED BACKORDERS AT TIME T IF INVENTORY LEVEL IS R

$t-\tau$ ———————— t

EVERYTHING ON ORDER AT TIME $t-\tau$ ARRIVES BY t

NOTHING NOT ON ORDER AT TIME $t-\tau$ WILL HAVE ARRIVED BY t

$\therefore$ ONLY WAY TO HAVE Y BACKORDERS AT TIME t IS TO HAVE R + Y DEMANDS IN INTERVAL $[t-\tau,t]$ <u>REGARDLESS OF WHAT'S ON-HAND, DUE-IN, DUE-OUT AT TIME $t-\tau$)</u>

$$B(R) = \sum_{X=R}^{\infty} (X-R)\, P(X;\lambda\tau)$$

Slide #10

FORMULAS DERIVATION
(Continued)

First define a quantity, for any given item at any using base or installation supply activity, called the inventory level. It is defined as the sum of the quantity of assets of that item on hand, plus the quantity due in (from base maintenance, depot resupply, or new procurement), less the quantity due out (i.e., backordered, usually to maintenance). Let this inventory level quantity be designated by $\underline{R}$. Note that, for any given $\underline{R}$, there may any combination of on-hand, due-in and backordered asset quantities. For example (overlay), if an activity's $\underline{R}$ is eight units, the activity would be at its level if it had only five assets on hand, but had three more due in. It would also be at its level if it had no assets on hand, four backorders in existence, and twelve units due in.

Continuing with the symbols used in this discussion, assume that the item has a constant resupply time to $\underline{\tau}$(Greek lower case letter "tau") days. ($\underline{\tau}$ need not be an integer.) The assumption that $\underline{t}$ is a constant is not essential to obtain the desired results that follow; it merely makes derivation of those results easier. Continuing, let $\underline{t}$ represent any random point in time, and let λ(Greek lower case letter "lambda") represent the average number of demands per day, or daily demand rate, at the specific activity for the specified item. Then the probability $p(X{:}\ \lambda\ T)$, of exactly $\underline{X}$ demands for the item in a time interval of days, i.e., at time interval for which the average number demands is $\lambda\ \underline{T}$. Finally, let $\underline{B(R)}$ equal the expected (roughly equivalent to the average) number of backorders for an item existing at any point in time, $\underline{t}$ at some using activity, if that activity's level for that item is $\underline{R}$.

AIR FORCE IMPLEMENTATION OF VSL FOR REPARABLES

FORMULAS DERIVATION

INVENTORY LEVEL = (ON-HAND) + (DUE-IN) - (BACKORDERS [DUE-OUT])

LET	R	=	INVENTORY LEVEL
	τ	=	CONSTANT RESUPPLY TIME
	t	=	RANDOM POINT IN TIME
	λ	=	DAILY DEMAND RATE
	$P(X;\lambda T)$	=	PROBABILITY OF X DEMANDS IN TIME INTERVAL OF LENGTH T
	$B(R)$	=	EXPECTED BACKORDERS AT TIME T IF INVENTORY LEVEL IS R

$t-\tau$ ——————————— t

EVERYTHING ON ORDER AT TIME $t-\tau$ ARRIVES BY t

NOTHING NOT ON ORDER AT TIME $t-\tau$ WILL HAVE ARRIVED BY t

$\therefore$ ONLY WAY TO HAVE Y BACKORDERS AT TIME t IS TO HAVE R + Y DEMANDS IN INTERVAL $[t-\tau, t]$ REGARDLESS OF WHAT'S ON-HAND, DUE-IN, DUE-OUT AT TIME $t-\tau$)

OH	DI	DO
5	3	0
0	12	4
8	0	0

$$B(R) = \sum_{X=R}^{\infty} (X-R)\, P(X;\lambda\tau)$$

$$B(8) = \underset{1BO}{(9-8)P(9)} + \underset{2BO}{(10-8)P\ 10} + \ldots$$

Slide #10

FORMULAS DERIVATION
(Continued)

Now consider an interval of τ days extending backward in time from any point in time, t, i.e., going forward in time from $(t-\tau)$ to t. Note that:

1. Every asset due in as of $(t-\tau)$ will be on hand by time t.
2. No assets not due in as of $(t-\tau)$ (i.e., which does not become due in until after $(t-\tau)$ will be on hand by time t.

Therefore, assuming the activity is "at" level R at time $(t-\tau)$ (i.e., (on hand) + (due-in) - (due-out) = R), the only way that there can be exactly Y backorders at time t is to have exactly (R+Y) demands during the time interval from $(t-\tau)$ to t. This is true no matter what the individual on-hand, due-in, and due-out quantities are at $t-\tau$, as long as they combine to equal R.

Thus, for example (same overlay), assuming (as before) an R of eight units, R is reflected by having eight assets on hand at $(t-\tau)$, with no due-ins or backorders. Then if there are no demands during the time interval, there are still eight on hand at time t. If there is one demand during that interval, there are seven on-hand plus one due-in, at time t. And so on, up to the point of eight demands during that time interval, which will give none on hand, with eight due-in, at time t. As soon as there are more than eight demands during the time interval, backorders will be reflected at time t, as shown (one backorder for nine demands, two backorders for ten demands, etc.). The expected number of backorders is the sum of the products of each possible number of backorders (one, two, etc.) multiplied by the probability of each number of backorders occurring. Of course, the probability of

Slide #10

FORMULAS DERIVATION

(Continued)

each number of backorders is precisely the probability of the corresponding number of demands resulting in that number of backorders, e.g., the probability of one backorder is probability of nine demands, etc. (same overlay). (Note that although the number of backorders theoretically approaches infinity, the corresponding computed probability approaches zero more rapidly, so that the indicated sum of the products has a finite value.)

Mathematically, the product sum can be shown in a shortened fashion, using the Σ (Greek capital letter "sigma") notation shown.

AIR FORCE IMPLEMENTATION OF VSL FOR REPARABLES

FORMULAS DERIVATION

NOTICE THAT:

EXPECTED BACKORDERS =
UNIT - DAYS BACKORDERED PER DAY

FURTHER:

$$\frac{\text{UNIT-DAYS BACKORDERED PER DAY}}{\text{UNITS DEMANDED PER DAY}} =$$

DAYS BACKORDERED PER DEMAND

OR

AVERAGE WAIT, OR DELAY, PER DEMAND

THUS, SINCE λ = DAILY DEMAND RATE

$$\frac{B(R)}{\lambda} = \frac{\sum_{X=R}^{\infty} (X-R)P(X;\lambda T)}{\lambda} = \text{AVERAGE WAIT (IN DAYS)}$$

AIR FORCE IMPLEMENTATION OF VSL FOR REPARABLES

FORMULAS DERIVATION

	DAYS									
REQ.	1	2	3	4	5	6	7	8	9	10
1		X	X	X	X	X				
2		X	X	X	X	X	X	X		
3						X	X	X		
4								X	X	
TOT.	0	2	2	2	2	3	2	3	1	0

2+2+2+2+3+2+3+1=17 BACKORDERS

$\frac{17}{10}$ = 1.7 BACKORDERS PER DAY

OR

5+7+3+2 = 17 BACKORDERS

$\frac{17}{10}$ = 1.7 BACKORDERS PER DAY

NOTICE THAT:

EXPECTED BACKORDERS =
UNIT - DAYS BACKORDERED PER DAY

FURTHER:

$\frac{\text{UNIT-DAYS BACKORDERED PER DAY}}{\text{UNITS DEMANDED PER DAY}}$ =

DAYS BACKORDERED PER DEMAND

OR

AVERAGE WAIT, OR DELAY, PER DEMAND

THUS, SINCE λ = DAILY DEMAND RATE

$$\frac{B(R)}{\lambda} = \frac{\sum_{X=R}^{\infty} (X-R)P(X;\lambda T)}{\lambda} = \text{AVERAGE WAIT (IN DAYS)}$$

Slide #11

FORMULAS DERIVATION
(Continued)

The expected number of backorders at any instant, B(R), can be approximated by observing the average number of backorders for a convenient unit of time, say each day. Thus, for example (overlay) a certain item might be observed at a certain activity for a ten-day period. The first day, no backorders are observed. The second day, two backorders occur, one of which lasts five days, and the other, seven days. A third backorder is observed, starting on day six and lasting three days, and a fourth on day eight for two days. Adding the number of backorders observed each day and dividing by the total days observed, as shown, yields an average of 1.7 backorders each day.

Actually, what is being observed is the number of unit backorder-days each day, since each backorder is taken as lasting for the entire day it was observed. This can be shown by adding the backorder durations, as shown.

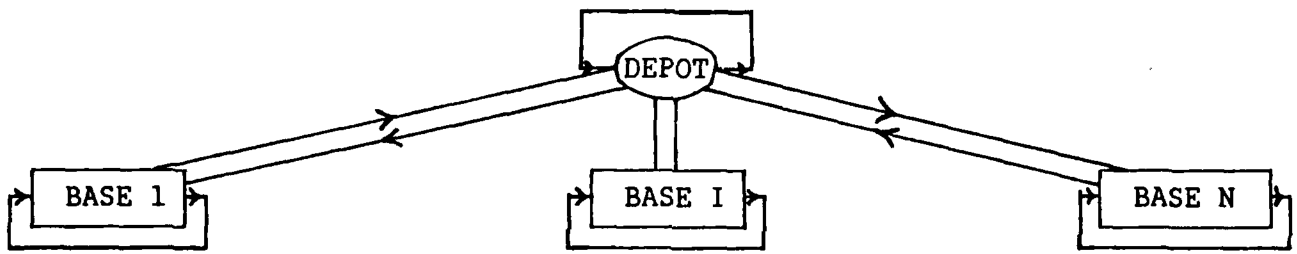
Therefore, the number of expected backorders is equivalent to the number of "unit-days backordered per day".

This terminology is useful when it is realized that: $\frac{\text{unit-days backordered per day}}{\text{unit(s) demand(ed) per day}}$ yields days backordered per demand, i.e., the average wait, or delay, per demand. This expresses backorders in a more meaningful measure of supply effectiveness and will become a system performance measure this Fall.

Using the previous symbology, the mathematical expression is as shown at the bottom of the slide.

AIR FORCE IMPLEMENTATION OF VSL FOR REPARABLES

FORMULAS DERIVATION



λ_I = MEAN DAILY DEMAND AT BASE I [λ_0 = DEPOT DEMAND RATE]
R_I = STOCK LEVEL AT BASE I [R_0 = DEPOT STOCK LEVEL]
F_I = PROBABILITY A FAILURE AT BASE I IS REPAIRED AT BASE I

[$1 - F_I$ IS PROBABILITY IT'S SENT TO DEPOT FOR REPAIR]

$$\text{(NOTICE } \lambda_0 = \sum_{I=1}^{N} (1-F_I)\lambda_I \text{)}$$

T_I = BASE REPAIR TIME AT BASE I
T_0 = DEPOT REPAIR CYCLE TIME
S_I = ORDER AND SHIP TIME BETWEEN DEPOT AND BASE I

BASE I RESUPPLY TIME, $E_I = F_I\ T_I + (1-F_I)[S_I + \text{DEPOT DELAY TIME}]$

Slide #12

FORMULAS DERIVATION
(Continued)

Now consider an item used by N bases and repaired both at the bases and at a depot, as diagrammed, with the simplifying assumption that all bases have the same demand rate, order and shipping time (O&ST), condemnations, base-not-repairable-this-station (NRTS) percent and base repair cycle time. Each base and the depot has its own daily demand rate, λ_i and stock level, R_i: (using the same notation as before). Now however, T_i represents only the repair cycle time. The order and shipping time between base i and the depot is represented by S_i, and each base has its own probability f_i that a reparable generation at that base is repairable at the base. The new base resupply time, E_i, is now a probability-weighted combination of the base repair cycle time and the base's NRTS resupply time. This latter is the sum of the base's order and shipping time and the depot delay time, i.e., the time between when the depot receives a repairable unit and when the depot ships a serviceable replacement. Note that, if R_o is zero, the depot delay time is the depot repair cycle time, T_o, and R_o is any non-zero quantity, the depot delay time will be something less then T_o. (The greater R_o, the less the depot delay time, approaching zero time delay as a limit.)

AIR FORCE IMPLEMENTATION OF VSL FOR REPARABLES

FORMULAS DERIVATION

$$\text{DEPOT DELAY TIME} = \sum_{X=R_0}^{\infty} (X-R_0)P_0(X;\lambda_0 T_0)/\lambda_0$$

$$E_I = F_I T_I + (1-F_I)[S_I + \sum_{X=R_0}^{\infty} (X-R_0)P_0(X;\lambda_0 T_0)/\lambda_0]$$

E_I NOT A CONSTANT; PALM'S THEOREM SAYS TREAT LIKE A CONSTANT

$$\therefore B_I (R_I) = \sum_{X=R_I}^{\infty} (X-R_I)P_I(X;\lambda_I E_I)$$

AIR FORCE IMPLEMENTATION OF VSL FOR REPAIRABLES

Slide #13

FORMULAS DERIVATION
(Continued)

Derive a mathematical expression for the depot delay time corresponding to the one derived earlier (Chart 11) and substitute this expression into the equation for the base resupply time, $\underline{E_i}$, as indicated.

This means, of course, that the base resupply times are not constants, as originally assumed (Chart 10). However, Palm's theorem can be used to show that if the probability density function of demands is a negative binomial distribution, base resupply time, E_i, can be treated as constants, rather than average values.

AIR FORCE IMPLEMENTATION OF VSL FOR REPARABLES

FORMULAS DERIVATION

SUPPOSE R_0 = DEPOT STOCK LEVEL

R_1 = BASE 1 STOCK LEVEL

$\vdots$

R_I = BASE I STOCK LEVEL

$\vdots$

R_N = BASE N STOCK LEVEL

$$\text{THEN } B(R) = B(R+R_0+R_1+\ldots R_N) = \sum_{I=1}^{N} B_I\ (R_I) = \sum_{I=1}^{N} \sum_{X=R_I}^{\infty} (X-R_I)P_I(X_I;\lambda_I E_I)$$

IS THE (TOTAL) AVERAGE BASE LEVEL BACKORDERS

Slide #14

FORMULAS DERIVATION
(Continued)

The expression for the total average base-level backorders resulting from allocating a "worldwide" quantity, R, is achieved by summing the expected (average) backorders at all the bases.

AIR FORCE IMPLEMENTATION OF VSL FOR REPARABLES

FORMULAS DERIVATION

$$\boxed{B^*(R) = \text{MIN } B(R)}$$

THAT IS FOR ALL POSSIBLE $R_0, R_1, \ldots R_I, \ldots, R_N$ SUCH THAT $R_0+R_1+\ldots R_N = R$[FIXED] SELECT $R^*_0, R^*_1, \ldots R_I^*, \ldots R_N^*$

THAT MINIMIZES B(R)

NOTE: THERE ARE

$$\frac{(R+N)!}{R!N!} = \left[\prod_{I=1}^{N} (R+I)\right] \Big/ N! \text{ WAYS TO SELECT } (R_0, R_1, \ldots, R_N)$$

EXAMPLE: IF $R = 20$
$N = 10$

$$\text{THERE ARE } \frac{30!}{20!10!} = \frac{2.6525 \text{ X } 10^{32}}{(2.4329 \text{ X } 10^{18})(3.6288 \text{ X } 10^{6})}$$

$$= \frac{26.525 \text{ X } 10^{31}}{8.8285 \text{ X } 10^{24}} = 3.005666 \text{ X } 10^{7} = 30,056,660 \text{ POSSIBILITIES}$$

Slide #15

FORMULAS DERIVATION
(Continued)

To accomplish the AFLC supply objective (Chart 8) for any constrained (fixed) R, the allocations of R among the N bases and the depot that minimize B(R) must be found.

From statistics theory, it can be shown that the formula for computing the number of ways of allocating R (identical) assets among (N+1) locations is as shown.

Thus even for only a "worldwide" quantity of twenty to be allocated as levels among ten bases (plus a depot), there are over thirty million possible allocation sets to consider. The simplifing assumption is made that all bases are identical, and only R+1 possible allocations between the base and depot are investigated in the D041A system. See "Recommendations for long term follow-on effort".

AIR FORCE IMPLEMENTATION OF VSL FOR REPARABLES

FORMULAS DERIVATION

SUPPOSE WE WISH TO FIND R $\ni$

$$cR + \sum_{N=0}^{\infty} \theta \frac{B^*(R)}{(1+I)^N} \text{ IS MINIMIZED}$$

WHERE: c = UNIT COST OF ITEM

θ = COST OF HAVING ONE UNIT OF ITEM BACKORDERED FOR ONE YEAR

$\frac{1}{(1+I)^N}$ = DISCOUNT FACTOR AFTER N YEARS

I.E., MINIMIZE $cR + \frac{\theta(I+1)}{I} B^*(R)$

AIR FORCE IMPLEMENTATION OF VSL FOR REPARABLES

FORMULAS DERIVATION

SUPPOSE WE WISH TO FIND R $\ni$

$$cR + \sum_{N=0}^{\infty} \theta \frac{B^*(R)}{(1+I)^N} \text{ IS MINIMIZED}$$

WHERE: c = UNIT COST OF ITEM

θ = COST OF HAVING ONE UNIT OF ITEM BACKORDERED FOR ONE YEAR

$\frac{1}{(1+I)^N}$ = DISCOUNT FACTOR AFTER N YEARS

I.E., MINIMIZE $cR + \frac{\theta(I+1)}{I} B^*(R)$

MINIMIZE $HcR + B^*(R)$

$cR + \frac{B^*(R)}{H}$

LET $H = \frac{I}{\theta(I+1)}$

THEN THE BACKORDER COST IS $\frac{\theta(I+1)}{I} B^*R$

Slide #16

FORMULAS DERIVATION
(Continued)

To establish the size of $\underline{R}$, standard inventory theory suggests $\underline{R}$ should be chosen so as to minimize the sum of two kinds of cost involved: the cost of having $\underline{R}$ units and the cost of the (minimized number of) backorders associated with $\underline{R}$, $\underline{B^*(R)}$.

The costs can be considered as either one-time (i.e., present-year) or continuing. In the latter case, we assume a constant discount factor, $\underline{i}$, for reducing future-year costs to their present year value, and the net result is a constant cost factor ($\frac{i+1}{i}$), times the present year cost. Therefore it makes no difference whether the cost factors are considered as one-year or continuing. To illustrate this, the cost expression to be minimized shows holding cost as one-time, backorder cost as continuing. *(overlay). With a little* algebraic manipulation, the backorder cost can be shown to be one-time.

AIR FORCE IMPLEMENTATION OF VSL FOR REPARABLES

FORMULAS DERIVATION

TAKE DERIVATIVE AND SET EQUAL TO ZERO

$$\frac{D}{DR}\left\{cR + \left[\frac{\theta(I+1)}{I}\right] B^*(R)\right\} = c + \left[\frac{\theta(I+1)}{I}\right]\left(\frac{B^*(R+1) - B^*(R)}{1}\right) = 0$$

$$\left(\frac{B^*(R) - B^*(R+1)}{1}\right)\left[\frac{\theta(I+1)}{I}\right] = c$$

$$\frac{B^*(R) - B^*(R+1)}{c} = \left[\frac{I}{\theta(I+1)}\right] = \xi$$

RULE: AS LONG AS $\frac{B^*(R) - B^*(R+1)}{c} \geq \xi$ KEEP ADDING STOCK.

AIR FORCE IMPLEMENTATION OF VSL FOR REPARABLES

FORMULAS DERIVATION

TAKE DERIVATIVE AND SET EQUAL TO ZERO

$$\frac{D}{DR}\left\{cR + \left[\frac{\theta(I+1)}{I}\right] B^*(R)\right\} = c + \left[\frac{\theta(I+1)}{I}\right]\left(\frac{B^*(R+1) - B^*(R)}{1}\right) = 0$$

$$\left(\frac{B^*(R) - B^*(R+1)}{I}\right)\left[\frac{\theta(I+1)}{I}\right] = c$$

$$\frac{B^*(R) - B^*(R+1)}{c} = \left[\frac{I}{\theta(I+1)}\right] = \xi$$

<u>RULE</u>: AS LONG AS $\frac{B^*(R) - B^*(R+1)}{c} \geqq \xi$ KEEP ADDING STOCK.

AS LONG AS THE MARGINAL GAIN $\left\{[B(R)-B(R+1)]\frac{\theta(I+1)}{I}\right\}$
IS GREATER THAN OR EQUAL TO THE MARGINAL COST (c)
KEEP ADDING STOCK.

Slide #17

FORMULAS DERIVATION
(Continued)

To find the value of R which minimizes the cost expression, differentiate the latter with respect to R (not precisely the case for backorder costs, which are a function of a discrete, rather than continuous, variable, R) and set the result (the rate of change of costs with R) equal to zero, which occurs when the sum of the two kinds of costs (inventory and backorder) is minimized.

After doing this, and with some simple algebraic manipulation, derive an expression setting the optimum reduction in expected backorder cost (the "marginal gain" (overlay)) equal to the cost of that reduction (the "marginal cost" (overlay)). This in turn leads to the establishment of an optimal ratio, ξ (Greek lower case letter "xi"), for the ratio of the reduction in expected backorders to the cost of achieving that reduction, with corresponding rule as shown. (The marginal analysis version of that rule is shown in the overlay.)

It should be pointed out that the ratio of backorder reductions to cost need not be set at ξ for each recoverable item. Instead, the ratio can be made constant over the entire range of recoverable items, or some subset of that range (e.g., all aircraft spares or all F-15-peculiar items), which optimizes the levels for all items in that subset relative to each other. This in effect optimizes the supply support for those items, subject to the cost constraint inherent in the backorders-per-inventory-dollar ratio established.

AIR FORCE IMPLEMENTATION OF VSL FOR REPARABLES

FORMULAS DERIVATION

WE HAVE SIX ITEMS AS FOLLOWS

ITEM	λT*	COST
1	3	\$ 100
2	3	\$ 200
3	3	\$ 400
4	3	\$ 800
5	3	\$2,000
6	3	\$4,000

* MEAN DEMANDS DURING RESUPPLY TIME

Slide #18

FORMULAS DERIVATION
(Continued)

A simple hypothetical example will serve to illustrate the *foregoing*. Here is a range of six items, with unit costs as shown. For ease in some of the later calculations, the items are assumed to have identical mean demands as shown, for a single user (no need to allocate among a depot and more than one user).

AIR FORCE IMPLEMENTATION OF VSL FOR REPARABLES

FORMULAS DERIVATION

	ITEM 1	ITEM 2	ITEM 3	ITEM 4	ITEM 5	ITEM 6
1ST ASSET	.009502[1]	.004752[2]	.002376[8]	.001188[13]	.000475[19]	.000238[26]
2ND ASSET	.008009[2]	.004004[5]	.002002[9]	.001001[14]	.000400[23]	.000200[29]
3RD ASSET	.005768[3]	.002884[7]	.001442[12]	.000721[18]	.000288[25]	.000144[32]
4TH ASSET	.003528[6]	.001764[11]	.000882[16]	.000441[21]	.000176[30]	.000088
5TH ASSET	.001847[10]	.000924[15]	.000462[20]	.000231[27]	.000092	.000046
6TH ASSET	.000839[17]	.000420[22]	.000210[28]	.000105[34]	.000042	.000021
7TH ASSET	.000335[24]	.000168[31]	.000084[35]	.000042	.000017	.000008
8TH ASSET	.000119[33]	.000060[36]	.000030	.000015	.000006	.000003
9TH ASSET	.000038	.000020	.000010	.000005	.000002	.000003
10TH ASSET	.000011	.000004	.000002	.000001		

Slide #19

FORMULAS DERIVATION
(Continued)

Using the previously shown, mathematics, it is possible to construct this table of backorder reductions per dollar invested in inventory. Since all six items have the same mean demand ($\lambda T=3$), the backorder reduction as each asset is added to R is the same for each item. Thus, for example, for the first asset,

$B^*(R=0)-B^*(R=1)=0.9502$, which, divided by item cost, gives the first row of table. Similarly, for the second asset added to R,

$B^*(R=1)-B^*(R=2)=0.8009$, which divided by item cost, gives the second row. And so on.

This permits establishing the order in which the depth of the items in this range will be reached, as shown by the exponent-appearing numbers, i.e., the first asset added would be one of Item 1, as would the second and third assets added. The fourth and fifth assets added, however, would be Item 2 assets, followed by a fourth asset of Item 1, etc. NOTE: The above ordering holds true only through the 34th asset chosen (the sixth Item 4 asset). The Seventh Item 3 asset and the eighth Item 2 asset were selected next in this instance only to give a total inventory cost of exactly $30,000 for reasons to be shown in the next slide. Otherwise, of course, the 35th and 36th assets added would have been the fifth Item 5 asset and the fourth Item 6 asset, respectively.)

If an arbitrary range-wide ratio of 0.0002 had been established leveling would have stopped with the 29th asset (the second Item 6 asset). If the ratio had been set at 0.0001, leveling would have stopped with the 34th asset.

AIR FORCE IMPLEMENTATION OF VSL FOR REPARABLES

FORMULAS DERIVATION

STOCK LEVEL	EQUAL PROTECTION	MARGINAL ANALYSIS
ITEM 1	4	8
2	4	8
3	4	7
4	4	6
5	4	4
6	4	3
TOTAL STOCK	24 UNITS	36 UNITS
COST	\$ 30,000	\$ 30,000
E (BACKORDERS)	1.92	1.07
FILL RATE	.647	.822
	NO. ≧ 5 NO. < 1	

Slide #20

FORMULAS DERIVATION
(Continued)

This compares the mariginal analysis based stockage of these six items with the equal protection stockage derived using meam demands plus a fixed safety level. Since all six items have the same mean demands, they have identical levels of four each, making the total stock 24 units at a cost of $30,000. It can be computed that the expected number of backorders (at any time, over all six items combined) for this stockage is 1.92, with a fill rate of 0.647. Compare this with the marginal analysis stockage, which, at the same cost (deliberately accomplished), provides 50% more units of stock, 44.3% fewer expected backorders, and a 27.0% increase in fill rate.

Note that marginal analysis based levels are equal to or larger than the corresponding equal protection levels for five of the six items. Only the most expensive item receives less protection under marginal analysis procedures than under a fixed safety level computation.

AIR FORCE IMPLEMENTATION OF VSL FOR REPARABLES

<u>PROGRAM DATA</u>

- o OIM PROGRAMS
  - oo FLYING HOURS
  - oo SQUADRON MONTHS
  - oo INVENTORY (EQUIPMENT) MONTHS
  - oo DRONE RECOVERIES
- o DLM PROGRAMS
  - oo PROGRAMMED DEPOT MAINTENANCE
  - oo ENGINE OVERHAULS
  - oo MANAGEMENT OF ITEMS SUBJECT TO REPAIR
- o PLANNED ADDITIONAL PROGRAMS (1982)
  - oo SORTIES
  - oo AMMO EXPENDITURES

AIR FORCE IMPLEMENTATION OF VSL FOR REPAIRABLES

Slide #21

PROGRAM DATA

Program data is used to forecast pipeline requirements as shown in the "Forecasting" segment of this presentation. Program data can be divided into 2 types - organizational intermediate maintenance data (failures generating during flying hours, squadron months, equipment months, or drone recoveries) and depot level maintenance (programmed depot maintenance, engine overhauls, or the MISTR program). Sorties and ammo expenditures will also be included beginning in 1982.

AIR FORCE IMPLEMENTATION OF VSL FOR REPARABLES

PROGRAM DATA

- o MECHANIZED MANUAL
- o UPDATED QUARTERLY
- o PAST PROGRAMS
  - oo TWO YEAR HISTORY
  - oo COMPUTE FACTORS AND PERCENTS
- o FUTURE PROGRAM
  - oo 6¼ YEARS + 3 YEARS RETENTION
  - oo COMPUTE PROJECTED REQUIREMENTS

Slide 22

PROGRAM DATA
(Continued)

The programs have a mechanized interface with the D041 and additional capability for building past or future programs by hand using a program element code and file maintaining them into the system. Mechanical and manual programs are updated quarterly.

While past programs retain 2 years of history, projected programs extend 6¼ years + a maximum 3 year retention period (unless the item is phasing out). The retention requirement is computed separately but uses the same method of projecting requirements based on future program using usage to past program ratios.

AIR FORCE IMPLEMENTATION OF VSL FOR REPARABLES

ESSENTIALITY

- o 3-POSITION MISSION ITEM ESSENTIALITY CODE (MIEC) IN D041
  - oo FIRST POSITION - SYSTEM ESSENTIALITY
  - oo SECOND POSITION - SUBSYSTEM ESSENTIALITY
  - oo THIRD POSITION - ITEM ESSENTIALITY
- o USES OF MISSION ITEM ESSENTIALITY CODE (MIEC)
  - oo MECHANIZED CAPABILITY NOT CURRENTLY USED
  - oo JUSTIFY AND ALLOCATE FUNDS
  - oo SCHEDULING ITEMS FOR REPAIR
  - oo IDENTIFYING WAR READINESS MATERIEL

Slide #23

ESSENTIALITY

A 3-position mission item essentiality code (MIEC) has been entered into the D041 to identify the importance of each item to Air Force readiness.

The first position refers to the weapon system or end item and is derived from Air Force Logistics Support priorities.

The second position, obtained from Major Air Command inputs, identifies by weapon system the criticality of each subsystem to the accomplishment of the assigned mission.

The third position is assigned by the equipment specialist and indicates how essential an item is to the operation of the subsystem.

The mechanized capability is not currently used in the D041. The MIEC is assigned to each application an item has to permit future expansion by AFLC to both allocate and aggregate resource requirements by weapon system in terms of essentiality.

Manual uses include justification of funds and their allocation if funded for less than 100% of the requirement. The essentiality code also assists the Air Logistics Centers (ALCs) to schedule items for repair and identifies those items which are to be included in the prestocked and prepositioned war readiness materiel.

The MIEC will be used to influence the mechanized computation after 1982 when other system changes will be completed.

AIR FORCE IMPLEMENTATION OF VSL FOR REPARABLES

IMPLEMENTATION ASSUMPTIONS

AN (S, S-1) INVENTORY MODEL

- STOCHASTIC DEMANDS
- NO OVERSHOOT OF THE REORDER LEVEL
- REQUISITION SIZE ALWAYS = 1
- CONTINUOUS REVIEW
- STEADY STATE
- NO NEGATIVE SAFETY LEVEL
- MODIFIED SINGLE - ECHELON
- DEMANDS DESCRIBED BY A NEGATIVE BINOMIAL DISTRIBUTION
- ASSUME CONSTANT RESUPPLY TIMES

Slide #24

IMPLEMENTATION ASSUMPTIONS

For recoverable items, the model is the (S, S-1) classical inventory model with stochastic demands and the following comments/modifications/exceptions: There is no overshoot of the reorder level --- An order is placed precisely at the reorder point. For this to be true, the requisition size must always be equal to 1. If the number of units demanded per requisition were a random variable, it would be possible to overshoot the reorder level. Therefore, an order is placed each time there is a demand--the transaction reporting or continuous review assumption, keeping the inventory position constant and the model steady-state. This is the only deviation from the total variable cost equation of DOD1 4140.39. The Air Force has a Department of Defense waiver allowing this difference. No negative safety level means the entire stock level is optimized and limited to 0 safety level. Because of the random nature of demands, allowing a 0 safety level will sometimes cause the system to run out of stock before the arrival of a procurement, thus incurring stock-out costs.

The single echelon assumption of the classical model is modified by using a single echelon model for the depot, computing the depot delay, and using the results in the single echelon model for the base.

The Air Force model uses a compound Poisson--negative binomial distribution--not a simple Poisson process to generate demands. (No distribution is specified in DODI 4140.39.) This allows more variability in demands since, for the Poisson process, the variance-to-mean ratio must equal 1.

Slide #24

IMPLEMENTATION ASSUMPTIONS
(Continued)

The constant procurement lead time assumption is also replaced with resupply times (combination of base repair cycle time, order and shipping time, and depot delay) which are not always constant. When the mean resupply time is computed, however, it is treated as if it were constant because the state probabilities and the optimal value of the inventory level are independent of the nature of the lead time distribution if the lead times are independent and the requisition size equals 1.

AIR FORCE IMPLEMENTATION OF VSL FOR REPARABLES

GOALS FOR USAGE OF MODELS

- o BUDGET FORMULATION
  - oo 92% BASE FILL RATE
  - oo 85% DEPOT FILL RATE
- o BUDGET EXECUTION
  - oo GOALS NOT CURRENTLY ADJUSTED FOR FUNDING CRUNCH

Slide #25

GOALS FOR USAGE OF MODELS

The model is used primarily for budget formulation. A 92% base fill rate was chosen for each computational group of items, currently for an aircraft series (e.g., F-111A, F-111E, or B52H). Based on a study of actual base and depot fill rates, 92% was chosen for the base to achieve the 85% depot fill rate goal levied by Headquarters U.S. Air Force (USAF).

These goals are not adjusted to live within funding shortfalls. The feasibility of selecting different fill rates for different weapon systems is, however, being investigated. Given a funding crunch, groups of items could be funded at less than 92%, depending on the impact on backorder rates and the priority of a weapon system. Buy guidelines are issued by the Headquarters AFLC to the ALCs for allocation of funds.

AIR FORCE IMPLEMENTATION OF VSL FOR REPARABLES

PARAMETERS AND CONSTRAINTS

- o PARAMETERS THAT CONTROL THE COMPUTATION
  - oo BUDGET SUPPORT OBJECTIVES (ξ)
    - ooo BSO TIMES UNIT COST = BACKORDER REDUCTION
    - ooo VALUES OF -.2 to -.00000009
  - oo FILL RATE TARGET (92%)

Slide #26

PARAMETERS AND CONSTRAINTS

The Parameters and Constraints section is divided into 3 parts: parameters that control the computation, elements that influence the computation, and details of the computation itself.

The budget support objective (BSO) is the shortage parameter set to control the safety level and can be defined as the cost one is willing to pay to reduce backorders or defined as the expected reduction in base-level backorders from adding one unit of stock to an item divided by the cost to attain that additional unit. This can also be expressed as the product of a BSO times a unit cost set equal to a backorder reduction.

The D041A system computes expected backorders for a stock level, adds a unit of stock, and computes expected backorders at that stock level, and takes the difference between the backorders to find the reduction in backorders. The BSO (input) is multiplied by either the procurement cost or the repair cost and compared to the reduction in backorders. Stock is added and the process repeated until the reduction in backorders is less than the BSO times the cost. Ninety-nine BSOs exist ranging from -.2 to -.00000009. A key is assigned to each BSO. Keys range from 1 to 99 and may be changed each quarter by Headquarters AFLC to closer approximate the desired fill rate. This is done by running the system using BSOs from the previous cycle, checking the resulting fill rate, and adjusting the keys accordingly.

A BSO is selected for each group of items, so that a 92% base fill rate is computed for the group. (Discussed in previous section "Goals for Usage of Models").

Slide #26

PARAMETERS AND CONSTRAINTS

(Continued)

The system will be modified this Fall to compute to other than a 92% fill rate target, if the command wishes to change this constant. This target can be manually adjusted by computational group at Hq. AFLC.

AIR FORCE IMPLEMENTATION OF VSL FOR REPARABLES

<u>PARAMETERS AND CONSTRAINTS</u>

o ELEMENTS THAT INFLUENCE THE COMPUTATION

oo PROCUREMENT COST

oo REPAIR COST

oo DISCOUNTING TECHNIQUE

ooo UNIT COST (1 - BASE NOT REPARABLE THIS STATION PERCENT)

oo ADJUSTMENT FOR NEGOTIATED LEVEL

ooo FIXED SAFETY LEVEL

$$FSL = \left(\sqrt{\frac{OST + BRC}{USERS}} \cdot 2.3\right) USERS$$

oo CURRENT ASSET POSITION

ooo SERVICEABLE ASSETS

ooo TOTAL ASSETS

Slide #27

PARAMETERS AND CONSTRAINTS

To recognize the fact that base-level backorders can be reduced by repair as well as by new procurement, repair costs are used to establish world-wide stockage levels on recoverable items not in a buy position. An item's repair cost is always equal to or less than its procurement cost.

The procurement or repair cost used in the objective function is discounted by multiplying it by 1 minus the base not-reparable-this-station percent. The idea is to provide more safety level for those items that will be sent back to the depot for repair. This alleviates an inequitable stockage mix whereby line replaceable units (LRUs-replaceable at a base) for older cheaper weapon systems were allocated more stock than shop replaceable units (SRUs-used to repair LRUs) for newer, more expensive weapon systems. Since most SRUs are repaired at the depot and therefore have high NRTS percents, the procedure discounts the cost, and allows higher stock levels to be computed but does not affect levels computed for LRUs with low NRTS percents. If an item's NRTS percent is greater than 90, the algorithm reduces it to 90 for this purpose. Costs are modified only for the purpose of this computation.

The negotiated base stock level represents the net increase required by bases over and above the D041A computed level. The average base stock level is computed by adding the OIM base O&ST requirement and the dividing by the number of users. This is compared to the "Adjusted Demand Level" quantity on AF form 1996 or the "Adjusted Level" from the D143H Master Summary. If the base level is greater, the difference is input to the D041A as an additive. A fixed safety level is computed for these items using the formula shown. A variable safety level is also computed for the item and compared to the sum of the fixed safety level and the negotiated level. The larger of the two is chosen as the safety level. (The fixed safety level provides about 1.5σ worth of protection.

Slide #27

PARAMETERS AND CONSTRAINTS
(Continued)

Items classified as Serialized Control and Reporting System or SCARS items are such high dollar value items that they would not normally have a variable safety level computed. They have a safety level computed using the fixed safety level formula.

The asset check is part of the procedure incorporated into the VSL algorithm to account for both repair cost and procurement cost instead of just procurement cost in establishing stock levels. After repair and buy stock levels for an item are computed based on marginal analysis, the levels are compared to the number of assets available for marginal analysis. The number of serviceable assets available is that quantity remaining after all requirements except for pipeline requirements (base and depot repair cycles, base order and shipping time, and procurement leadtime) have been satisfied. The total number of assets available for marginal analysis is also netted of all requirements except pipeline requirements and includes serviceable assets, if there are any.

Available serviceable assets are applied up to the maximum stockage level which is the amount of stock at which the expected backorders are less than .001. If the available serviceable assets are not sufficient to meet the repair stockage level, the available reparable assets are applied to make up the deficit and achieve all or part of the repair stockage level. If the available serviceable and reparable assets are not sufficient to meet the buy stockage level, enough new assets are bought to make up the deficit.

AIR FORCE IMPLEMENTATION OF VSL FOR REPARABLES

PARAMETERS AND CONSTRAINTS

o ELEMENTS THAT INFLUENCE THE COMPUTATION

oo SEGMENTS OF THE COMPUTATION

ooo LEADTIME REQUIREMENTS

CONDEMNATIONS

ooo OVERHAUL REQUIREMENT

NON-JOB ROUTED REPARABLES IN DEPOT REPAIR CYCLE

ooo OIM REQUIREMENT

REPARABLES IN BASE REPAIR CYCLE

BASE ORDER AND SHIP TIME

DEPOT REPAIR CYCLE

Slide 28

PARAMETERS AND CONSTRAINTS
(Continued)

An item's requirement is computed in 3 segments. The leadtime requirement is the projected condemnations over a period of time necessary to achieve new procurement. It includes condemnations from the overhaul segment and the OIM segment.

The overhaul requirement is based on the expected number of reparables in the depot repair cycle pipeline due to non-job routed demands coming off the overhaul line. A non-job routed reparable is one which has to be repaired at a site other than where the overhaul is being conducted.

The OIM requirement consists of the expected number of repairables in the base repair cycle and base order and ship time pipelines and the expected number of repairables in the depot repair cycle pipeline. Both base and depot pipleline quantities are based on world-wide demands.

AIR FORCE IMPLEMENTATION OF VSL FOR REPARABLES

PARAMETERS AND CONSTRAINTS

o ELEMENTS THAT INFLUENCE THE COMPUTATION

oo PROBABILITY DENSITY FUNCTION

ooo NEGATIVE BINOMIAL IF MEAN DEMANDS $\leqq 20$

ooo NORMAL IF MEAN DEMANDS > 20

oo VARIANCE TO MEAN RATIO

ooo $V{:}M = 1.132477\mu^{.3407513}$

ooo IF $V{:}M \leqq 1$, $V{:}M = 1.00001$

Slide #29

PARAMETERS AND CONSTRAINTS
(Continued)

For each of the 3 computation segments, the probability distribution of demands is either negative binomial if mean demands are less than or equal to 20, or normal if mean demands are greater than 20. The cut-off point is 20 and a switch is made to the normal distribution because it serves as a good approximation for the discrete negative binomial distribution and because distributions of large samples approach the normal distribution as a limit.

The mean demand is used in the variance to mean ratio with the proper probability density function to determine the stock level. The variance-to-mean formula was derived from a study of sample items in 1973 using a 2 year demand history. Its use will be explained in subsequent charts.

AIR FORCE IMPLEMENTATION OF VSL FOR REPARABLES

PARAMETERS AND CONSTRAINTS

- o ELEMENTS THAT INFLUENCE THE COMPUTATION
  - oo MINIMUM REQUIREMENTS
    - ooo LEADTIME SEGMENT

      AVERAGE NUMBER OF CONDEMNATIONS
    - ooo OVERHAUL SEGMENT

      AVERAGE NUMBER OF NON-JOB ROUTED REPARABLES IN DEPOT REPAIR CYCLE
    - ooo OIM SEGMENT

      AVERAGE NUMBER OF REPARABLES IN BASE AND DEPOT REPAIR CYCLES AND BASE O & ST
  - oo MAXIMUM REQUIREMENT
    - ooo STOCK + BACKORDERS < .001
  - oo MAXIMUM DEPOT STOCK LEVEL

    IF DEPOT DELAY < .00001 · DRCT

    $$\text{WHERE DEPOT DELAY} = \frac{\text{EDO} \cdot \text{DRCT}}{\text{DRCRQ}}$$

    EDO = EXPECTED DEPOT BACKORDERS
    DRCT = DEPOT REPAIR CYCLE TIME
    DRCRQ = DEPOT REPAIR CYCLE REQUIREMENT

Slide #30

PARAMETERS AND CONSTRAINTS

(Continued)

The minimum stock level permitted is the pipeline requirement for each item which is intended to prevent gaps in support. Pipeline requirements consist of the leadtime condemnation requirement, the non-job routed repair cycle requirement, the OIM depot repair cycle requirement, and the OIM base order and shipping time and repair cycle requirement. The first two are strictly depot requirements, the OIM depot repair cycle requierment influences stock levels at both the base and the depot, and the base order and shipping time and repair cycle influence primarily the base stock level.

The maximum stock level for an item is that amount of stock at which expected backorders are less than .001. The algorithm computes this level for each of the three computation segments. This is intended to prevent low cost items from achieving excessive stock levels and was an arbitrary but not capricious target based on trials of various upper bounds during the system's experimental phase. (Alternatives to this maximum are being investigated).

The maximum depot stock level is reached when the depot delay is less than a small percentage of the depot repair cycle time.

PARAMETERS AND CONSTRAINTS

- INTRICACIES OF THE COMPUTATION

WHEN MEAN ≦ 20, PROBABILITIES ARE COMPUTED BY:

$$\left[\frac{(K+X-1)!}{(K-1)!X!}\right] \left[\frac{(Q-1)^{X}}{Q^{K+X}}\right]; \qquad \begin{array}{l} Q > 1 \\ K > 0 \\ X = 0,\ 1,\ 2,\ 3,\ \ldots \end{array}$$

THIS IS CONVERTED TO THE FOLLOWING RECURSIVE FORMULA:

$$P(X+1) = P(X)\left(\frac{Q-1}{Q}\right)\left(\frac{K+X}{X+1}\right)$$

THE FIRST TERM IS

$$P(0) = \left(\frac{1}{Q}\right)^{K}$$

DERIVED BY SUBSTITUTING ZERO IN THE FIRST FORMULA

WHERE: P(X) = PROBABILITY OF X DEMANDS
Q = VARIANCE -TO-MEAN
$K = \frac{\text{MEAN}}{Q-1}$
X = NUMBER OF DEMANDS

AIR FORCE IMPLEMENTATION OF VSL FOR REPAIRABLES

Slide #31

PARAMETERS AND CONSTRAINTS

(Continued)

This section covers the formulas used for computing the stock level, expected backorders, and resulting fill rate using the negative binomial distribution and the normal distribution.

If mean demands are less than or equal to 20, a probability of demand occurring is computed for x=0,1,2,3,...based on the the probability of the previous quantity of demands.

AIR FORCE IMPLEMENTATION OF VSL FOR REPARABLES

PARAMETERS AND CONSTRAINTS

- INTRICACIES OF THE COMPUTATION

  WHEN MEAN $\leqq$ 20,

  TO COMPUTE EXPECTED BACKORDERS B(S) AT A STOCK LEVEL S:

$$B(S) = \sum_{X=S}^{\infty} (X-S)P(X)$$

$$B(S+1) = \sum_{X=S+1}^{\infty} X-(S+1)\ P(X)$$

COMBINE TO PRODUCE

$$B(S) = B(S-1) + \sum_{X=0}^{S-1} P(X) - 1; \quad S \geqq 1$$

WHERE S = STOCK
P(X) = PROBABILITY OF X ASSETS IN THE PIPELINE (DEMANDS)

Slide #32

PARAMETERS AND CONSTRAINTS
(Continued)

The probabilities are then used to compute expected backorders for each possible stock level. Again, backorders for stock level s are based on backorders for the previous stock level (s-1). Note that the backorders for the zero asset position are equal to the mean. Stock is added one unit at a time until the BSO times the cost reaches the backorder reduction.

AIR FORCE IMPLEMENTATION OF VSL FOR REPARABLES

PARAMETERS AND CONSTRAINTS

- INTRICACIES OF THE COMPUTATION

  WHEN MEAN $\leq$ *20,*

$$\text{FILL RATE} = \sum_{X=0}^{S} P(X)$$

Slide #33

PARAMETERS AND CONSTRAINTS

(Continued)

The fill is the sum of the probabilities of occurrence of demands from 0 to $\underline{s}$. This is actually a "ready rate" or the probability of not having a backorder.

AIR FORCE IMPLEMENTATION OF VSL FOR REPARABLES

PARAMETERS AND CONSTRAINTS

- EXAMPLE OF AN ITEM'S STOCK LEVEL COMPUTED USING THE NEGATIVE BINOMIAL DISTRIBUTION

NEGATIVE BINOMIAL PROBABILITY

$$P(X+1) = P(X)\left(\frac{Q-1}{Q}\right)\left(\frac{K+X}{X+1}\right)$$

WHERE $P(X)$ = PROBABILITY OF X DEMANDS
X = NUMBER OF DEMANDS
Q = VARIANCE TO MEAN RATIO

$$K = \frac{\mu}{Q-1}$$

AND $P(0) = \left(\frac{1}{Q}\right)$

GIVEN A MEAN OF 2

$$Q = 1.132477\mu^{.3407513}$$
$$Q = 1.434187$$
$$K = 4.606310$$

P(0) = .20	P(3) = .15	P(6) = .02
P(1) = .26	P(4) = .09	P(7) = .01
P(2) = .22	P(5) = .04	P(8) = .01

AIR FORCE IMPLEMENTATION OF VSL FOR REPAIRABLES

Slide #34

Viewgraphs self-explanatory.

AIR FORCE IMPLEMENTATION OF VSL FOR REPARABLES

PARAMETERS AND CONSTRAINTS

$$\sum_{X=S}^{\infty} (X-S)P(X)$$

FOR STOCK = 0

X	S	(X-S)	P(X)	(X-S)P(X)
0	0	0	.20	0
1	0	1	.26	.26
2	0	2	.22	.44
3	0	3	.15	.45
4	0	4	.09	.36
5	0	5	.04	.20
6	0	6	.02	.12
7	0	7	.01	.07
8	0	8	.01	.08
				1.98

AIR FORCE IMPLEMENTATION OF VSL FOR REPAIRABLES

Slide #35

Viewgraphs self-explanatory.

AIR FORCE IMPLEMENTATION OF VSL FOR REPARABLES

PARAMETERS AND CONSTRAINTS

$$\sum_{X=S}^{\infty} (X-S)P(X)$$

FOR STOCK = 1

X	S	(X-S)	P(X)	(X-S)P(X)
0	1	0	.20	0
1	1	0	.26	0
2	1	1	.22	.22
3	1	2	.15	.30
4	1	3	.09	.27
5	1	4	.04	.16
6	1	5	.02	.10
7	1	6	.01	.06
8	1	7	.01	.07
				1.18

AIR FORCE IMPLEMENTATION OF VSL FOR REPAIRABLES

Slide #36

Viewgraphs self-explanatory.

AIR FORCE IMPLEMENTATION OF VSL FOR REPARABLES

PARAMETERS AND CONSTRAINTS

STOCK	EXPECTED BACKORDERS	DECREASE IN BACKORDERS	DECREASE IN BACKORDERS DIVIDED BY UNIT COST $100)
0	1.98		
1	1.18	.80	.0080
2	.64	.54	.0054
3	.32	.32	.0032
4	.15	.17	.0017
5	.07	.08	.0008
6	.03	.04	.0004
7	.01	.02	.0002

IF TARGET BUDGET SUPPORT OBJECTIVE = .0022, STOCK 4 UNITS

(RULE: AS LONG AS $\frac{B*R - B*(R+1)}{C} \geqq \xi$ KEEP ADDING STOCK)

AIR FORCE IMPLEMENTATION OF VSL FOR REPAIRABLES

Slide #37

Viewgraphs self-explanatory.

AIR FORCE IMPLEMENTATION OF VSL FOR REPARABLES

PARAMETERS AND CONSTRAINTS

$$\text{FILL RATE} = \sum_{X=0}^{S} P(X)$$

$$= .20 + .26 + .22 + .15 + .09$$

$$= .92$$

AIR FORCE IMPLEMENTATION OF VSL FOR REPAIRABLES

Slide #38

Viewgraphs self-explanatory.

AIR FORCE IMPLEMENTATION OF VSL FOR REPARABLES

PARAMETERS AND CONSTRAINTS

- o INTRICACIES OF THE COMPUTATION

WHEN MEAN > 20,

TO PREDICT STOCK TO MEET THE REQUIRED BACKORDER REDUCTION:

$$SK \cong \left(0.5 - \Delta BO\right) \left(\frac{0.14822401}{0.29670819 - (0.5 - \Delta BO)^2} + \frac{0.0014532591}{0.2505217 - (0.5 - \Delta BO)^2} + 2.04890 \right)$$

WHERE ΔBO = BSO * COST OR BACKORDER REDUCTION

SK = NUMBER OF DEVIATIONS FROM MEAN

THEN FOR STOCK, S,

$$S = SK * \sigma + M$$

WHERE $\sigma = \sqrt{\text{VARIANCE}}$

M = MEAN

Slide #39

PARAMETERS AND CONSTRAINTS

(Continued)

If mean demands are greater than 20, the stock level is computed using rational approximations to normal probability functions. $F(x)$ is represented by the backorder reduction, and x, the number of standard deviations the desired stock level is from the mean, can be found using the formula shown. These approximations were developed by Mr. P. F. Strong of Arthur D. Little, Inc., Cambridge, Mass. and can be found on p.93 of R. G. Brown's *Decision Rules for Inventory Management*.

AIR FORCE IMPLEMENTATION OF VSL FOR REPARABLES

PARAMETERS AND CONSTRAINTS

- o INTRICACIES OF THE COMPUTATION
  - oo WHEN MEAN > 20,

    TO COMPUTE BACKORDERS FOR A STOCK LEVEL:

    $SK = \frac{S-M}{\sigma}$ WHERE: SK = THE NUMBER OF DEVIATIONS THE STOCK LEVEL IS FROM THE MEAN

    S = STOCK LEVEL

    M = MEAN

    σ = STANDARD DEVIATION

    $$PEBO = -(0.5 * SK) - \frac{9.8575631}{8.189133+SK^2} + \frac{172025.85 + 6998.8869\ SK^2}{107496.82+638.3668\ SK^2+SK^4}$$

    WHERE PEBO = NUMBER OF DEVIATIONS IN THE BACKORDERS

    THEN BACKORDERS FOR A GIVEN STOCK LEVEL

    $EBO = PEBO * \sigma$

    WHERE EBO = BACKORDERS

    σ = STANDARD DEVIATION

Slide #40

PARAMETERS AND CONSTRAINTS
(Continued)

Expected backorders are computed in a similar manner using the stock level computed on the previous chart to compute partial expectations or the number of standard deviations this stock level is from the mean. Sigma (standard deviation) is the divisor to find SK (the number of standard deviations the stock level is from the mean) to convert the equations from their standardized normal form. Sigma is then multiplied back in to the partial expected backorders to find expected backorders.

AIR FORCE IMPLEMENTATION OF VSL FOR REPARABLES

PARAMETERS AND CONSTRAINTS

- o INTRICACIES OF THE COMPUTATION
  - oo WHEN MEAN > 20,

    TO COMPUTE THE FILL RATE FOR AN ITEM:

    $SK = \frac{S-M}{\sigma}$ WHERE: SK = THE NUMBER OF DEVIATIONS THE STOCK LEVEL IS FROM THE MEAN

    S = STOCK LEVEL

    M = MEAN

    σ = STANDARD DEVIATION

    THEN THE PROBABILITY OF NOT HAVING A FILL IS

    $$NF = 0.5 - \frac{6.41979SK}{75.33103+SK^2} - \frac{6.76151SK+0.91230SK^3}{21.8468+7.03823SK^2+SK^4}$$

    AND THE ITEM FILL RATE IS

    $$FR = 1 - NF$$

Slide #41

PARAMETERS AND CONSTRAINTS
(Continued)

The formula used to find the probability that a stock $\underline{s}$ will not be sufficient to satisfy a demand is the inverse of the first of these 3 formulas: given x we find $F(x)$.

AIR FORCE IMPLEMENTATION OF VSL FOR REPARABLES

SENSITIVITY OF PARAMETERS AND CONSTRAINTS

o PARAMETERS THAT CONTROL THE COMPUTATION

oo SHORTAGE PARAMETER

ooo LARGE BUDGET SUPPORT OBJECTIVE → MORE STOCK COMPUTED

oo CONSTRAINT ON BUDGETING

ooo FILL RATE GOAL

Slide #42

SENSITIVITY OF PARAMETERS

The larger the shortage parameter set to control the safety level, the budget support objective within the computation, the more stock may be allocated. A change in BSOs of 10 keys (effectively cutting the BSO at least in half) is usually the difference between 2 BSO s with a range of 7 BSOs computed. The system computes the requirement using BSOs from the last quarters's computation, then recomputes to closer approximate the fill rate goal of 92%. Manual adjustments to the BSOs may be made and the system run again.

On some items even the extreme values of BSOs will not permit a 92% fill rate to be computed because of prohibitive cost of the item; the system provides a greater depth of stock for inexpensive items instead of expensive ones. Because the fill rate is an average of a group of items, some items in the group will have a higher and some a lower fill rate to achieve the average. That is, some will receive more support than others.

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AIR FORCE IMPLEMENTATION OF VSL FOR REPARABLES

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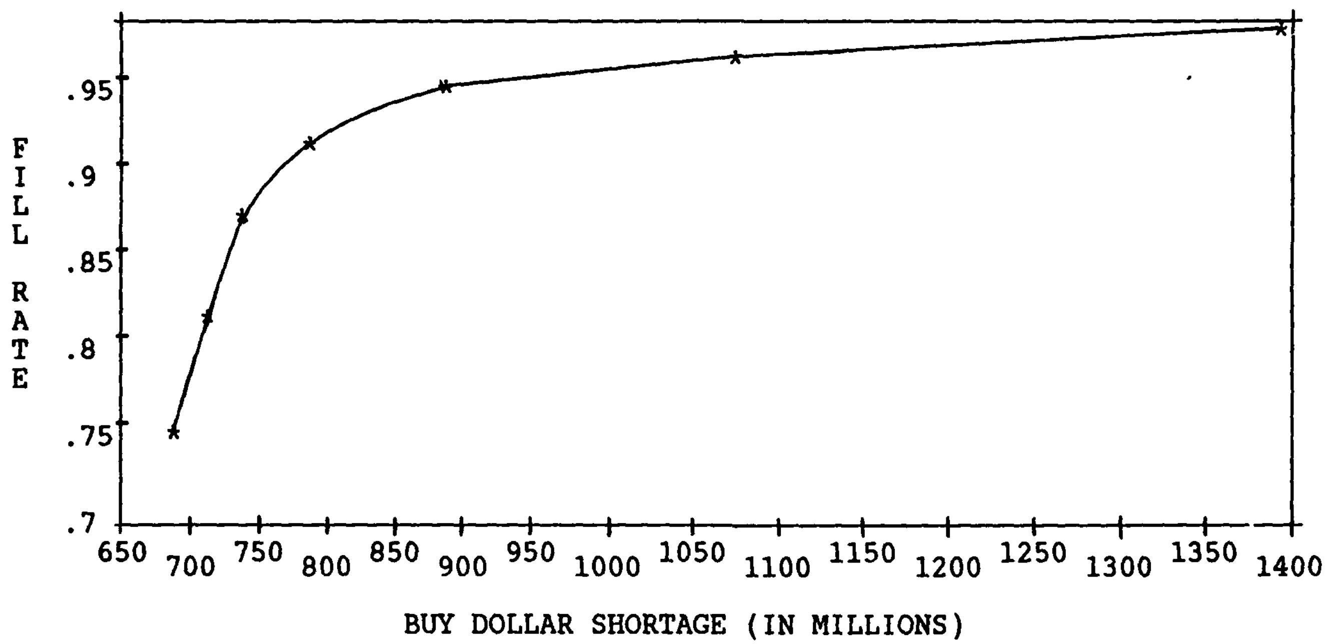

Slide #42A

SENSITIVITY OF PARAMETERS
(Continued)

The graph shows the range of 7 BSOs displayed for Budget Program 15, Aircraft Replenishment Spares. Computed fill rate is plotted against the buy dollar deficit which represents the requirement for each item at its buy point minus whatever assets will be on-hand at that point. The requirement reaches out through FY81. The 92% fill rate target is the middle one and falls in a cost-effective area of the curve; at higher fill rates (like 97%) support would not be improved as much for the dollars spent, and below that area support would rapidly diminish per dollar decrease.

AIR FORCE IMPLEMENTATION OF VSL FOR REPARABLES

SENSITIVITY OF PARAMETERS AND CONSTRAINTS

SENSITIVITY OF OTHER ELEMENTS

- o ENCOURAGE STOCK LEVELS
  - oo HIGH BASE NRTS PERCENT
  - oo LOW PROCUREMENT OR REPAIR COST
  - oo PIPELINE REQUIREMENT (MINIMUM)
    - ooo BASE VS DEPOT STOCK
- o RESTRICT STOCK LEVELS
  - oo .001 BACKORDERS (MAXIMUM STOCK LEVEL)
  - oo WHEN COMPUTING USING THE NORMAL DISTRIBUTION

$$SK = \frac{\text{BASE STOCK LEVEL - MEAN}}{\text{SIGMA}}$$

    - ooo IF SK > +4, SK = 4 FILL RATE = .9999
    - ooo IF SK < -4, ΔBO = 1, EBO = MEAN - BSL, FILL RATE = 0
  - oo AVAILABLE ASSETS
- o COUNTERBALANCING EFFECTS
  - oo LOW MEAN DEMANDS
    - ooo NEGATIVE BINOMIAL DISTRIBUTION VS LOW VARIANCE
  - oo HIGH MEAN DEMANDS
    - ooo NORMAL DISTRIBUTION VS HIGH VARIANCE

Slide #43

SENSITIVITY OF OTHER ELEMENTS

Other elements also affect the computation. The primary influences are divided into those that encourage and those that restrict stock levels. Of course, where a high value of one of these elements encourages stock to be computed, the converse is also true.

ENCOURAGE STOCK LEVELS.

A high NRTS percent tends to encourage stock levels because of the [cost (1-NRTS)] adjustment (see chart 43A).

NATIONAL STOCK NUMBER   1430003354854BR

DO YOU WANT TO PRINT OUT INPUT DATA - YES OR NO
=YES

BUDGET SUPPORT OBJECTIVES

-0.00099643	KEY 28
-0.00038803	38
-0.00015110	48
-0.00005884	58
-0.00002291	68
-0.00000892	78
-0.00000109	88

PROCUREMENT COST	12098.61
REPAIR COST	1662.28
LEADTIME CONDEMNATION REQUIREMENT	0.
NON JOB ROUTED REPAIR CYCLE REQUIREMENT	0.
OIM DEPOT REPAIR CYCLE REQUIREMENT	0.28205500
OIM BASE O&ST + REPAIR CYCLE REQUIREMENT	1.45280400
NUMBER OF USERS	3.
NUMBER OF SERV AVAILABLE FOR MARGINAL ANALYSIS	0
NUMBER OF ASSETS AVAILABLE FOR MARGINAL ANALYSIS	3
NEGOTIATED LEVEL	1
NOT REPARABLE THIS STATION %	0.04

BSO	EXPECTED BACKORDERS	PROJECTED FILL RATE	BASE STOCK LEVEL	DEPOT STOCK LEVEL
1	1.297331	66.7417	1.	0.
2	1.297331	66.7417	1.	0.
3	1.297331	66.7417	1.	0.
4	1.297331	66.7417	1.	0.
5	0.306796	91.4549	4.	0.
6	0.075839	97.7837	6.	0.
7	0.006248	99.8066	9.	1.

NEGOTIATED LEVEL AND ASSETS SET TO Ø
NRTS = 4%

MINIMUM REQUIREMENT 1
MAXIMUM REQUIREMENT 13

BSO	EXPECTED BACKORDERS	PROJECTED FILL RATE	BASE STOCK LEVEL	DEPOT STOCK LEVEL
1	1.297331	66.7417	1.	0.
2	1.297331	66.7417	1.	0.
3	0.191317	94.6193	5.	0.
4	0.050355	98.4916	6.	1.
5	0.032463	99.0437	8.	0.
6	0.006248	99.8066	9.	1.
7	0.000643	99.9796	12.	1.

NRTS = 90%

MINIMUM REQUIREMENT 1
MAXIMUM REQUIREMENT 13

Slide #43A

SENSITIVITY OF OTHER ELEMENTS

SAMPLE: The sample item shows stock levels computed for 2 different NRTS percents. The low percent did not allow much stock to be computed on this particular item, even as the BSO key changed from 28 - 58. The high NRTS percent decreased the cost because of the discounting technique [cost (1-NRTS)] and caused the safety level to increase.

Because the divisor of the objective function is cost, low procurement or repair cost allows more stock to be computed. Conversely, a substantial increase in the procurement or repair cost of an item could cause the safety level to be computed at one or two units less than on the previous quarterly computation cycle.

The minimum requirement prevents stock from falling below the repair cycle and order and shipping time levels. In addition, the type of pipeline requirement makes a difference in whether stock is allocated to the base or depot. For example, the leadtime condemnation requirement and the non-job routed requirement are depot requirements so some stock must be allocated to the depot to cover them. When the only pipeline requirement is the base order and ship time and the base repair cycle, all stock is allocated to the base, rather than the depot.

RESTRICT STOCK LEVELS.

The primary upper limit on stock level is the minimum number of backorders a stock level can satisfy. Another constraint occurs when the stock level is computed using the normal approximation formulas (mean demand greater than 20). If the computed stock level is greater than 4 standard deviations above the mean, it is set equal to +4 standard deviations in the formulas to compute expected backorders. The fill rate is set to .9999 and

Slide #43A

SENSITIVITY OF OTHER ELEMENTS
(Continued)

stock is limited to that level. If the computed stock level is less than 4 standard deviations below the mean, the backorder reduction is equal to 1, expected backorders are equivalent to the mean minus the stock level, and the fill rate is set to 0.

The application of total assets to the computed requirement has the effect of restricting the repair requirement (i.e., an item is not bought if it can be repaired, and the repair requirement is limited by the number of repairable carcasses available).

The effects of the variance and of distribution of demands tend to be counterbalancing. For items with low demand rates, the negative binomial distribution of demands gives more backorders (and therefore, tends toward more stock level) than does the normal. These items, however, will have a lower variance than items with high demand rates because in a variance to mean ratio of the form variance = aM^b, the variance increases (although at a decreasing rate) as mean demands increase. The result can be a greater safety level for high demand items to account for the additional variance.

AIR FORCE IMPLEMENTATION OF VSL FOR REPARABLES

<u>PROBLEM AREAS IN IMPLEMENTATION AND USE OF MODELS</u>

- o COMPUTED BACKORDER AND FILL RATES VS. ACTUAL RATES
- o INDENTURE RELATIONSHIPS
  - oo EFFECT OF AVAILABLE SRUs ON THEIR ASSOCIATED LRUs
- o DISTRIBUTION SYSTEM VERSUS REQUIREMENTS COMPUTATION SYSTEM
- o BACKORDERS AS A MEASURE OF AIRCRAFT CAPABILITY

Slide #44

PROBLEM AREAS

There is a disjoint between computed rates and actual statistics compiled by a base or depot. Backorders are computed as "any point in time" while actual statistics are backorders outstanding on the last day of the month. The computed fill rate is currently a composite base and depot (although primarily base) and in that respect, does not parallel actual statistics. This Fall, the computed fill rate will be broken out between base and depot.

The D041/D041A system does not explicity consider indenture relationships (part within component, SRU within LRU) and the fact that spares for lower indenture items serve to reduce the repair time of their "parent" items. Thus, the unavailability of an item needed to repair a higher level assembly is not reflected in the "parent" item's requirement and spares may not be in optimal balance. A study is in progress to compare the D041 computation with a levels-of-indenture computation and asses the difference.

Another problem is that the distribution system does not currently match the requirements computation system. The D041/D041A computes worldwide requirements while an individual base computes only its own requirement. This creates a tendency for higher base-computed stock levels, especially for high-cost items. For low-cost items, the Do41/D041A computes higher levels than does the base and the base is not requisitioning up to those higher levels.

Backorders do not necessarily measure aircraft capability or readiness; fewer backorders does not always mean more aircraft are supportable. For example, assume the worldwide inventory of a particular aircraft type is 40, and that during the last month, 100 supply

Slide #44

PROBLEM AREAS
(Continued)

requisitions were submitted and 90 of them were filled from stock on-hand (10% backorder rate, 90% fill rate). All 10 of these backorders could be for the same item, possibly grounding of the 10/40 aircraft, which is only 75% of the aircraft available even though the overall item fill rate was 90%.

AIR FORCE IMPLEMENTATION OF VSL FOR REPARABLES

RECOMMENDATIONS FOR LONG TERM FOLLOW-ON EFFORT

- o D028, CENTRAL LEVELING SYSTEM
  - oo THEORETICALLY,

    FOR R = 0, 1, 2, ...

    COMPUTE

    $B^*(R) = \text{MIN } B(R)$

    $\frac{(R+N)!}{R!N!}$ POSSIBILITIES FOR EACH POSSIBLE R

    AND KEEP GOING AS LONG AS

    $B^*(R-1) - B^*(R) \geqq C\xi$

Slide #45

RECOMMENDATIONS FOR LONG TERM FOLLOW-ON EFFORT

Differences between the distribution system and the requirements computation system should be resolved by the central leveling system, D028, mentioned in the "formulas derivation" section. Theoretically, all values of $\underline{R}$ (the inventory level) must be methodically searched starting with R=0, then R=1, then R=2, etc.; and the optimum allocation of $\underline{R}$ among the item's $\underline{N}$ users found (remembering how many possible allocations of R assets among N users there are). Continue this process until the backorder reduction per dollar figure reaches whatever constraining value of $\underline{\xi}$ has been imposed.

AIR FORCE IMPLEMENTATION OF VSL FOR REPARABLES

RECOMMENDATIONS FOR LONG TERM FOLLOW-ON EFFORT

- o D028, CENTRAL LEVELING SYSTEM
  - oo PRACTICALLY, THIS IS A TWO STEP APPROACH

1. D041A DETERMINE R BY ASSUMING ALL USERS (BASES) ARE IDENTICAL.

   (THUS FIND $R = R_0+R_1+R_2+'''R_\eta$ GIVEN $R_1=R_2=R_3='''R_\eta$)

2. D028 ONCE R IS DETERMINED, RELAX THE IDENTICAL USER ASSUMPTION

   (THUS GIVEN R DETERMINE $R_0,\ R_1,\ R_2,'''R_\eta \ni R_0+R_1+'''R_\eta = R$)

Slide #46

RECOMMENDATION FOR LONG TERM FOLLOW-ON EFFORT
(Continued)

As was pointed out in the "Formulas Derivation" section, this becomes too much of a computer load for any reasonable values of R and N. Therefore, to ease that load, the problem was artifically divided onto two parts, or steps.

In the first step (in D041A), all users are assumed to have the same (i.e., average or standard) characteristics which enter into the computation, such as daily demand rate, base repair rate, base repair cycle time, and order and shipping time. This means that, for any value of R, there can be at most only (R+1) possible allocations to investigate, rather than $\frac{(R+N)!}{R!N!}$ i.e., R_0 (depot allocation)=0, R_0=1, ..., R_0 = R. (The R - R_0 remaining assets are always allocated as uniformly as possible among the N users, since they are assumed identical.)

In the second step (in D028), the assumption of identical users is done away with, and the D041A-determined R quantity is allocated among the wholesale (depot) and retail (base) echelon users in accordance with their individual characteristics. This solution investigates every possible base, depot stock level combination for distributing the worldwide stockage level. For example, if the worldwide level is 20 units, then every combination of base, depot allocations beginning with zero assets at the depot, 20 assets at the base and ending with 20 assets at the depot and zero at the base, will be investigated. The base, depot combination which provides for the minumim number of base-level backorders is the best solution. The bases will use this system to determine their stock levels. The programming for the D028 has been written and is awaiting validation and a production test.

AIR FORCE IMPLEMENTATION OF VSL FOR REPARABLES

<u>RECOMMENDATIONS FOR LONG TERM FOLLOW-ON EFFORT</u>

- o PUSH DISTRIBUTION SYSTEM
  - oo SERVICEABLE ASSETS DISTRIBUTED TO USERS
- o AIRCRAFT READINESS MEASURE

Slide #47

RECOMMENDATIONS FOR LONG TERM FOLLOW-ON EFFORT
(Continued)

A follow-on to the Central Leveling System is the Push Distribution System which involves actual optimal distribution of serviceable assets from the ALC to the users as these assets become available to the ALC from procurement or depot level repair without waiting for users to requisition them. This is still in a conceptual phase.

The Air Force is also investigating ways of solving the backorder vs aircraft capability problem and is examining aircraft readiness measures with an eye to making the D041A reflect an aircraft capability measure, perhaps as the objective function. One of the measures that has potential but is still in a testing phase is an aircraft availability rate.

AIR FORCE IMPLEMENTATION OF VSL FOR REPARABLES

RECOMMENDATIONS FOR LONG TERM FOLLOW-ON EFFORT

- ONE POSSIBLE AIRCRAFT READINESS MEASURE - AIRCRAFT AVAILABILITY

IF B_J = WORLDWIDE EXPECTED BACKORDERS FOR ITEM J

T = TOTAL NUMBER OF AIRCRAFT

A_J = QUANTITY OF ITEM J PER AIRCRAFT

THEN: $\frac{B_J}{T' A_J}$ = PROBABILITY A RANDOM HOLE FOR ITEM J IS EMPTY

$1 - \frac{B_J}{T' A_J}$ = PROBABILITY A RANDOM HOLE FOR ITEM J IS NOT EMPTY

$\left(1 - \frac{B_J}{T' A_J}\right)^{A_J}$ = PROBABILITY THAT ITEM J IS NOT MISSING ON A RANDOM AIRCRAFT

$\prod_{J=1}^{N} \left(1 - \frac{B_J}{T' A_J}\right)^{A_J}$ = PROBABILITY THAT ITEM J IS NOT MISSING ON A RANDOM AIRCRAFT

$T \cdot \prod_{J=1}^{N} \left(1 - \frac{B_J}{T' A_J}\right)^{A_J}$ = EXPECTED NUMBER OF AIRCRAFT NOT DOWN FOR AN ITEM

Slide #48

RECOMMENDATIONS FOR LONG TERM FOLLOW-ON EFFORT
(Continued)

This takes the backorder measure a step further. Start with computed backorders, total number of aircraft, and the quantity of an item j per aircraft and transform them into the probability that a random aircraft will not be waiting for a component j.

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